STUDIES IN DISEASES OF CEREALS AND GRASSES

I NEW ANTHRACNOSE DISEASES OF CERTAIN CEREALS AND GRASSES

II THE FUNGUS OF WHEAT SCAB AS A SEED AND SEEDLING PARASITE. ALSO GENERAL ON SMALL GRAINS.

OHIO

Agricultural Experiment Station.

WOOSTER, OHIO, U. S. A., APRIL, 1909.

BULLETIN 203

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BULLETIN

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STUDIES IN DISEASES OF CEREALS AND GRASSES.

BY A. D. SELBY AND THOS. F. MANNS.

I NEW ANTHRACNOSE DISEASES OF CERTAIN CEREALS AND GRASSES.

The following pages present the results of a single year's definite investigations of this particular disease conducted in the field and laboratory. While it has not been possible to learn in this time as much as it is desirable to know concerning this new Anthracnose, which is of such general occurrence upon our small grains and many of the grasses grown in rotation with them, an early presentation of the facts thus far brought to light seems justified from every point of view. The apparently widespread occurrence of this disease, together with conditions of its possible survival from year to year and from crop to crop, make the final status of such a trouble difficult to determine. In presenting the results obtained, reservation is made for further publication of later discoveries. That such a disease should have attained such wide distribution before its discovery and identification may well excite remark, yet careful search throughout the literature of plant diseases has not brought to light evidence that the disease has been previously recognized.

WHEAT SHRIVELING AND ITS CAUSES.

The shriveling of the grain in wheat has long been known to occur, often as a phenomenon difficult to explain. The wheat growers have learned by experience how widely different may be the promise and performance of a given field. In this respect the better drained lands are possibly at an advantage over those less completely drained, but many otherwise successful growers of wheat and other crops have found the shriveling of the grain a bar to profitable wheat growing.

Doubtless in many cases the shriveling is properly attributed to the attacks of rust upon the wheat plant, but that the amount of shriveling should at times be so great in the absence of an aggressive development of rust has raised in the minds of the writers, serious question as to the adequacy of rust attacks to explain the grain shriveling which actually takes place in a given season.

PREVIOUS EFFORTS BY THE DEPARTMENT TO DISCOVER THE CAUSE OF SHRIVELING.

So well had he become convinced of this that in 1904 the Station Botanist undertook to ascertain by experimental applications of fertilizers and lime whether some corrective of possible physiological weakness in the wheat plant might be applied on wheat fields where shriveling was so serious. In that effort he was assisted by Messrs. Alva Agee and A. L. Walker, Cheshire, Ohio; Wm. Brush, Franklin Furnace, Ohio; and Judge J. M. Van Meter, Piketon, Ohio, who cordially cooperated with him in the trials to discover a further cause of the trouble or relief from it. It is proper to record in this connection that these several observers described the early growth and the appearance of the grain fields upon the bottom lands under investigation as usually satisfactory, but that this development even in the matter of heading out and fairly healthful foliage would not insure an adequate return in grain.

Oftentimes just after the filling of the grain had begun a noticeable change in color took place, and this was very evidently accompanied by more or less general whitening and blighting of the wheat heads. This blighting as studied by the Department did not show as a specific disease upon the wheat head or portions of it, such as occurs in the case of wheat scab (Fusarium), but rather as an arrest of development and premature ripening of the grain, whether the kernels were completely or but partially developed. It is a matter of gratification to the Station Botanist that the investigations described in the following pages yield a sufficient explanation of the phenomena above described and appear to solve the question of cause in these instances so far as pertains to our Ohio winter wheat. (See Fig. 3, Page 206).

That at times under peculiar conditions the attacks of rust may be aggressive enough to account for grain shriveling and the loss of yield observed, the writers do not undertake to question; it will appear, however, that we have in the Anthracnose of wheat and rye an adequate cause for much of this whitening and blighting of the plants precedent to the filling and ripening of the grain. The particular symptoms and suggestions more or less essential to the identification of the Anthracnose will be given on subsequent pages and need not here be stated.

CENTRIFUGE EXAMINATIONS OF GRAIN SAMPLES AND THEIR RESULTS.

Most persons are more or less familiar with the apparatus known as a cream separator, so common in American dairy districts. In principle this separates the cream from the milk by making use of the difference in specific gravity of the two, instead of simple gravity separation in crocks, whereby the lighter fat-rich cream rises to the top and is skimmed off. The separation is effected by a rapidly revolving disk or cylindrical device, by which the cream with its contained fat is permitted to pass out by one orifice and the relatively fat-free sweet milk by another. A more exact application of the same method is made in the Babcock Tester which is familar to most persons. In these tubes for fat testing, the neck is narrow and provided with graduations by which the percentage is directly read from this scale. After addition of the necessary acid to the milk sample the tube is so placed in a rotating holder that with rapid turning the wide basal portion turns outward and the narrow open neck turns inward. In the inwardly turned neck the fat rises by being displaced in fact by the heavier fat-free milk. Some small 2 and 4-tube forms of the Babcock Tester are very similar to the centrifuge here shown. In milk testing the *lighter* fat is sought–in searching for spores of fungi, etc., in grain washings the *heavier* particles are sought in the separation. The principle involved in these practical machines is the separation of the bodies of lower and higher specific gravity, contained in a common medium, as a result of the centrifugal force exerted on these bodies, when contained in a rapidly revolving tube.

If we conceive of this tube or of tubes as rotating rapidly in the horizontal plane, the mouth opening toward the center of rotation and the bottom toward the outer periphery, we would naturally expect the heavier particles to move toward the bottom of the tube, that is, toward the outer point of revolution. This principle is applied in bacteriological laboratories by means of an apparatus called a centrifuge, an illustration of which is herewith given. The physician's centrifuge illustrated, is a form adapted to the separation of sputum or other secretions for microscopic examination. (Fig. 1.)

The two tubes of glass are contained in outer protecting cases of aluminum and when at rest these hang in a vertical position in the machine, but when rotation is set up by turning the crank of the centrifuge, the centrifugal force causes these to assume a horizontal position and the condition before described, in which the opening of the tube is toward the center of the circle about which movement takes place, with the bottoms outward, is fully realized. These centrifuges are used for the clinical examinations of blood, urine, milk and sputum and for the collection of organisms or solids contained in water, chemical substances, etc.

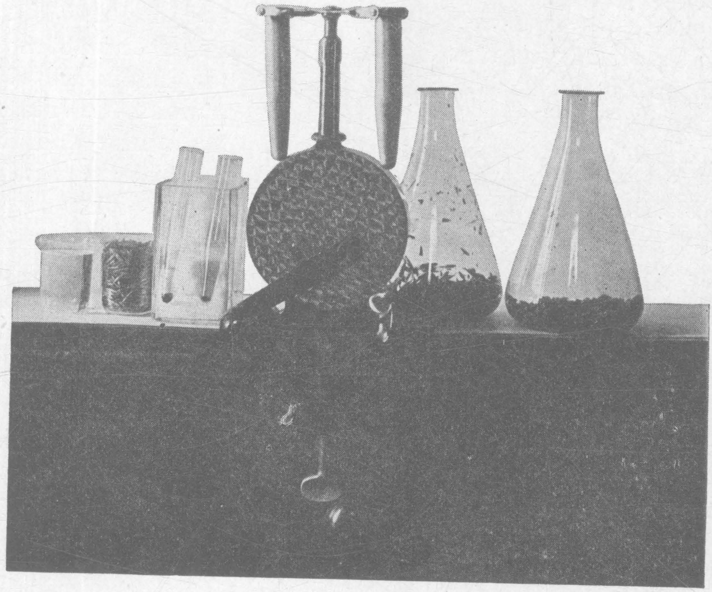

Fig. I. Showing a physician's centrifuge and additional apparatus used in making tests for smut spores and spores of other diseases adhering to the exterior of the seed grain. *From a photograph by T. F. Manns.*

When rotated at a high speed by means of the crank, the metal cases which now hang vertically turn with the points outward and rotate in a horizontal plane.

The wheat and oats shown in the flasks at the right are samples from which washings have been made by very thorough shaking of the flask and contents. The small beakers at the extreme left show the amounts of grain (75 cc.) and distilled water (50 cc.) respectively used for a test.

The two glass tubes in glass container at left are used by insertion in the metal holders of the centrifuge, and here show by the dark precipitates in the bottom, the amount of smut and other particles from the samples of wheat and oats in the flasks. All X 1-5.

One of these placed in our laboratory enables us to make examinations of many sorts.* Washings from the soil in which diseased plants occur or washings of samples of seed grain can be placed in the centrifuge and there subjected to the rotation and consequent centrifugal effects. The results are almost amazing; the washing from a sample of smutted oats will give a black layer in the bottom of the inner glass tube consisting of the spores of the oat smut fungus. Washings of samples of wheat will give at the bottom of the tube the spores of all the various fungi found in the wheat; these include the spores of loose smut, the spores of stinking smut, the spores of scab, and the spores of any other grain diseases which may occur. That this method is effective will be shown by reference to Table I. The Assistant Botanist made a large number of these examinations during the winter of 1907-8. These included 114 centrifuge examinations of separate wheat samples, 75 of separate samples of oats, rye, emmer and barley. The following tables give in brief form the results of these examinations.

TABLE I. Showing results of test made as to the efficiency of physician's centrifuge in precipitating various spores of fungi, and bacteria from aqueous solutions. Duration of test, 5 minutes; rate, 2000 revolutions per minute.

Test No.	Spores used	Results
1	Wheat Anthracnose, *Colletotrichum cereale*	Came down readily.
2	*Fusarium oxysporium*, (potato-rot)	Came down readily, water perfectly clear.
3	Stinking smut of wheat	Came down readily, water perfectly clear.
4	Loose smut of wheat	Came down readily, water perfectly clear.
5	Bacterial mixture	Apparently ½ came down, water still cloudy.
6	*Alternaria* species	Came down readily, leaving water clear.
7	*Helminthosporium* species	Came down readily.
8	*Penicillium glaucum*	Came down readily, though water not quite clear.
9	*Periconia pycnospora*	Came down readily.
10	Streak disease of wheat†	Came down readily.

†Newly observed. Fungus not identified.

The above table proves how effectively the centrifuge separates all spores contained in an aqueous solution.

* Bolley appears to have been the first to apply the centrifuge to the examination of seed washings to determine the spores found in them. The writer while assistant under Prof. Bolley in 1901-02 made extensive use of the centrifuge in the study of fungus spores carried in flax seed. A report of the use of the centrifuge in diagnosing plant diseases is given by him, see H. L. Bolley, Proc. Soc. Prom Agr. Sci., 1902, pp. 82-85. (T. F. M.)

TABLE II. Showing results of centrifuge examinations of wheat samples from Ohio, not including Wayne county.

Source	No. of samples	No. showing scab	No showing stinking smut	No. showing loose smut	No. showing Anthracnose	Appearance of samples			
						Very Good	Good	Fair	Shr'nken or poor
Amesville	1	1	0	1	1			1	
Amelia	1	1	1	1	1	1			
Ashville	3	3	3	2	3		1	2	
Batavia	1	1	1	0	1		1		
Cheshire	3	3	0	3	3		1	2	
Chillicothe	4	4	2	2	1		2	1	1
Everett	1	1	0	0	1	1			
Franklin Furnace	1	1	0	0	1		1		
Franklin	1	1	1	0	0		1		
Fremont	1	1	1	1	1		1		
Gilbert	2	2	1	1	2		1		1
McGuffy	1	1	1	1	1		1		
New Richmond	1	1	1	0	1	1			
Peninsula	3	2	1	1	2		2		1
Sharpsburg	3	3	2	3	2			3	
West Richfield	1	1	0	0	1	1			
Zanesville	1	1	0	1	1		1		

TABLE III. Summary of results of all centrifuge examinations of wheat samples including percentage of Ohio samples showing different diseases.

Source	No. of samples	No. showing scab	No. showing stinking smut	No. showing loose smut	Anthracnose		Appearance of samples			
					Samples containing Anthracnose	Samples having abundant Anthracnose	Very good	Good	Fair	Shr'nken or poor
Wayne county	66	66	49	53	64	39	25	31	10	..
Ohio excluding Wayne county	29	28	16	19	24	10	4	13	8	4
Totals—Ohio	95	94	65	72	88	49	29	44	18	4
Percentages	..	98.9	68.4	75.8	92.6	51.6	30.5	46.3	19.2	4.2
Winter wheat district outside Ohio (Indiana)	2	2	2	1	1	1	..	2	..	
Spring wheat district in northwest (North Dakota)	16	1	4	11	0	0	6	1	..	*9

* Frosted samples.

Among the samples examined were those of a large number of varieties of wheat grown at the Station, in the Station's fertilizer and variety test plots and kindly supplied by the Department of Agronomy. Other samples especially solicited by reason of previous studies in the shriveling of wheat upon their respective premises were contributed by many persons.

To the following gentlemen are due our best thanks for their kind helpfulness in this work; Judge J. M. Van Meter, Chillicothe, O.; W. F. Knellinger, Zanesville, O.; H. P. Sorensen, Peninsula, O.; J. A. Stokes, Fremont, O.. Harvey Perrin, Amelia, O.; A. L. Walker, Cheshire, O.; Lowell Roudebush, New Richmond, O.; W. A. Brush, Franklin Furnace, O.; Edgar Monegan, Peninsula, O.; L. H. Glazier, Amesville, O.; L. H. Ward, Ashville, O.; Geo. A. Harris, Sharpsburg, O.; John Courtright, Ashville, O.; J. H. Griffith, Everett, O.; R. A. Charlton, West Richfield, O.; E. C. Patchell, Batavia, O.; W. McGuffy, McGuffy, O.; Chalmer Menefee, Gilbert, O.; Geo. E. Walker, Cheshire, O.; J. Geo. Snyder, Chillicothe, O.; C. C. Easton, Franklin, O.

It will be observed from the summary given in Table III that the washings of 95 Ohio wheat samples were examined by the centrifuge method. Of these 98.9 percent showed the presence of scab, 68.4 percent the presence of stinking smut, 75.8 percent the presence of loose smut, 92.6 the presence of certain amounts of Anthracnose spores, while 51.6 percent of them showed an abundance of Anthracnose spores, (See Plates I and II for illustrations of these various spores).

It may be said in further explanation and verified from illustrations on subsequent pages, that the spores of the various Anthracnoses are identifiable by reason of a certain form and having peculiar structural markings; we were, therefore, expecting to discover the summer development of the Anthracnose on wheat in the season of 1908, because the spores of such a fungus had been located in the grain crop of the year before, and our expectations were more than fully realized as may be seen below.

As is shown in Table IV as well as in Plate I, centrifuge examinations were made of a large number of oat samples and of a few samples each of barley, rye and the spelts. The results of these examinations are summarized in Table IV. It will be observed that a high proportion of both the oat samples and the rye samples examined by the centrifuge showed the presence of the spores of Anthracnose.

DISCOVERY OF THE ANTHRACNOSE DISEASE ON RYE.

On June 10, 1908, specimens of diseased heads of rye were received from Mr. Matthias Harmon, Atwater, Ohio. Microscopic examinations of these specimens showed the heads to be attacked by a parasitic Anthracnose fungus which caused partial or total dying of the spike or head according to the point of attack, somewhat after the manner of wheat heads in case of attack by scab.

1 2 3

Fig. 2. Showing three of earliest rye heads received at the laboratory, attacked by Anthracnose.

Spike No. 1 is attacked near base (at point a) and portion above is dead.
Spike No. 2 is attacked near middle (at point b), portion above also dead.
Spike No. 3 shows a head, of which grain is badly shrunken from Anthracnose attack on stem below. All five-sixths natural size. *From a photograph by T F. Manns.*

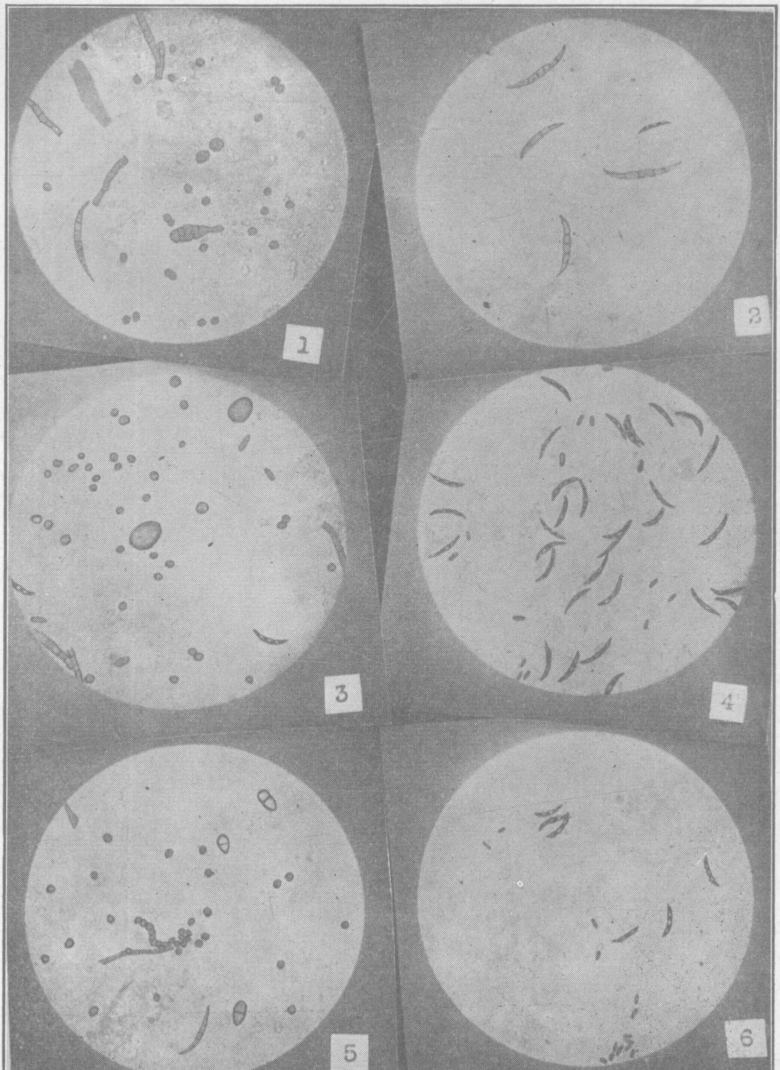

PLATE I. Photomicrographs, magnified about 180 times, of centrifuges from washings of oats and rye; prints were lightly retouched with India ink. (*Manns.*)

No. 1. From oats, showing one scab, one *Alternaria* and many smut spores.
No. 2. From oats, showing one Anthracnose and several scab spores.
No. 3. From oats, showing two rust, one Anthracnose and many smut spores.
No. 4. From rye, showing many Anthracnose spores, also many smaller, straight hyaline spores.
No. 5. From oats, showing many smut, one scab and three spores of *Cephalothecium roseum;* the latter a fungus causing much mold in oats the season of 1907.
No. 6. From rye, showing the guttulate characters of the spores of the anthracnose fungus (*Colletotrichum cereale*, n. sp.)

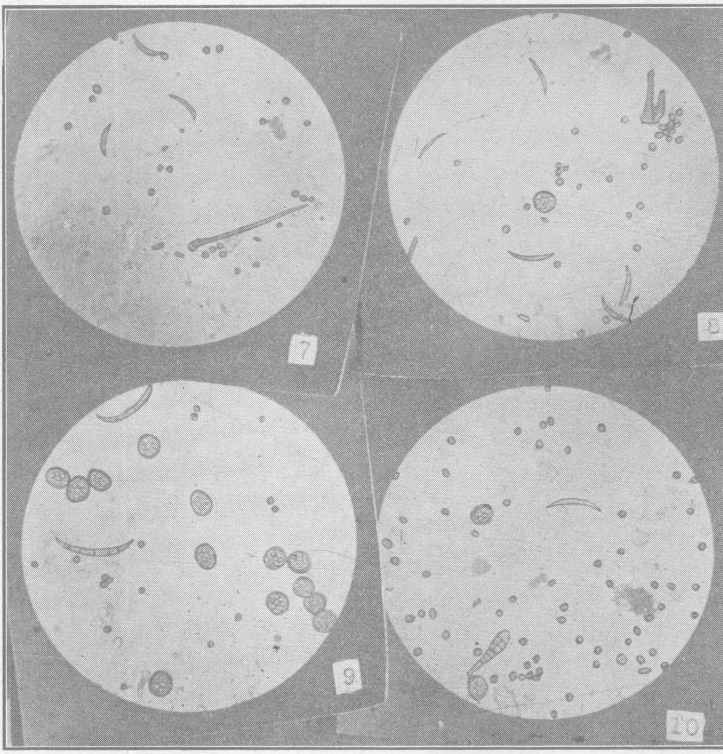

PLATE II. Photomicrographs, magnified about 180 times, of centrifuges from washings of wheat; prints lightly retouched. (*Manns.*)

No. 7. From wheat, showing setum and spores of Anthracnose disease, also loose smut of wheat.

No. 8. From wheat, showing Anthracnose spores, loose smut, stinking smut and portions of the setæ of Anthracnose.

No. 9. From wheat, showing the *Fusarium* causing scab; loose smut and stinking smut.

No. 10. From wheat, showing *Alternaria* sp., loose smut, stinking smut and scab spores.

The illustrations Fig. 2 and Plates III and IV will show the appearance of these rye heads after being attacked by the fungus. On ordinary superficial examination the only difference between the appearance of these and of heads of wheat or rye attacked by the scab fungus is the absence of any pink covering due in those cases to the causal fungus, one of the pink molds, *Fusarium*. Indeed one is liable to miss the real cause of the dying of the rye heads, except he take great pains to go over the same very carefully. At the base of the dead portion in these heads were discovered dark clusters or acervuli of the fungus causing the death of that portion of the head above the point of attack. Microscopic examinations showed this fungus to be an Anthracnose and the dark color more or less due to the black hairs (*setæ*) which are characteristic of the Anthracnoses of this particular group and which will appear in the illustrations of the details of the fungus itself.

On the 22nd of June the Station Botanist visited the grounds of Mr. Harmon and there noted the conditions existing. Three different sowings had been made, in two of which the seed used had been purchased at a warehouse in Alliance; a second lot was seeded from rye obtained at a different warehouse and a third lot was seeded from that obtained in the neighborhood. The seed rye of the first lot was represented to have been grown by a farmer near Marlboro, Ohio. At any rate this first lot showed very heavy injury from Anthracnose; an estimate indicated 50 percent or more of the rye stalks to be attacked, while in the other two lots the proportion attacked by the disease was less. The crop was cut heavily by it. It was estimated, at the time, that about one-third of the yield to be expected from the growth of straw would be lost from the disease; subsequent reports from Mr. Harmon indicate that while there was enough straw for 75 bushels of grain he only obtained 25 bushels from a total area, in excess of three acres. These figures indicate a loss of two-thirds instead of one-third of the crop from this new disease. Examination of all the rye fields passed in the vicinity of Atwater, possibly ten in number, showed the same disease present in the rye. The disease was subsequently collected in practically every rye field visited over the whole of the state.

TABLE IV. Summary of results of all centrifuge examinations of samples of oats, barley, rye and the spelts. All samples from Ohio.

Kind of grain	No. of samples	No. showing scab	No. showing rust	No. showing smuts	No. showing Anthracnose	No. showing mold* *Cephalothecium*	Appearance of samples			
							Very good	Good	Fair	Shr'nk-en or poor
Oats	67	64	61	56	56	54	25	18	7	17
Barley	4	4	4	4	0	2	1	2	1	
Rye	2	1	0		2	0			1	1
Spelt and Emmer	3	3	2	2	0	2	1			2

* *Cephalothecium roseum*. See Plate I.

PLATE III. Showing head and upper portion of culm of rye attacked by Anthracnose, *Colletotrichum cereale*, n. sp.

1. Shows spike with glumes cut away toward base where the dark hairs of the fungus show on the original specimen; the portion above is dead from the attack.

2. Shows the spots (*acervuli*) of the Anthracnose distributed along the stem and on the sheath, with specially marked development near the joint. All magnified 2½ times.

From a photograph by T. F. Manns.

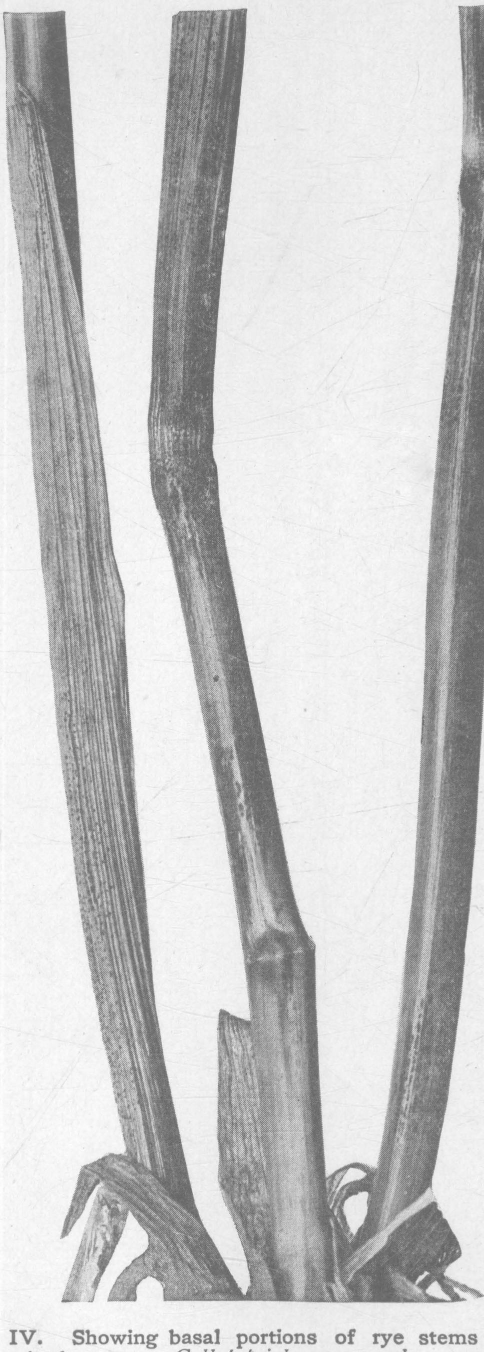

PLATE IV. Showing basal portions of rye stems with adhering sheaths attacked by the Anthracnose, *Colletotrichum cereale*, n. sp. The spots on the sheath show the acervuli of the fungus which in these specimens attacked the roots of the rye and developed with marked virulence about the joints of the culms. Magnified 2 1-2 times. *From a photograph by T. F. Manns.*

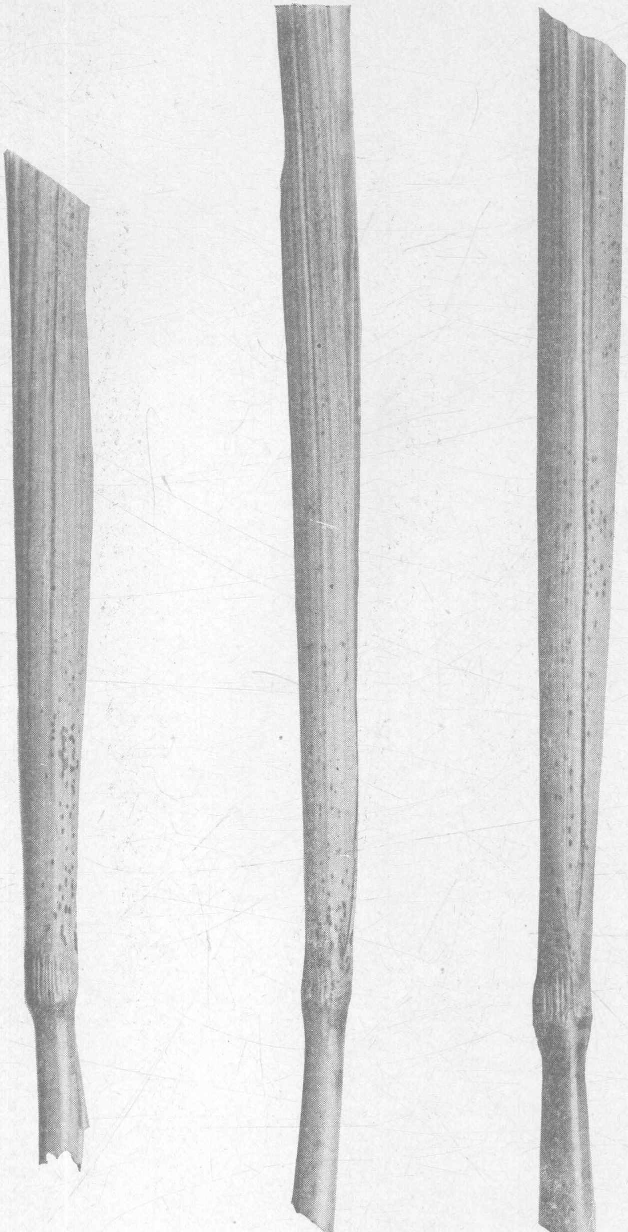

PLATE V. Showing sections of basal portions of culms of wheat with both stems and sheaths attacked by Anthracnose. The dark spots are the acervuli of *Colletotrichum cereale*, n. sp. Magnified 2 1-2 times.

From a photograph by T. F. Manns.

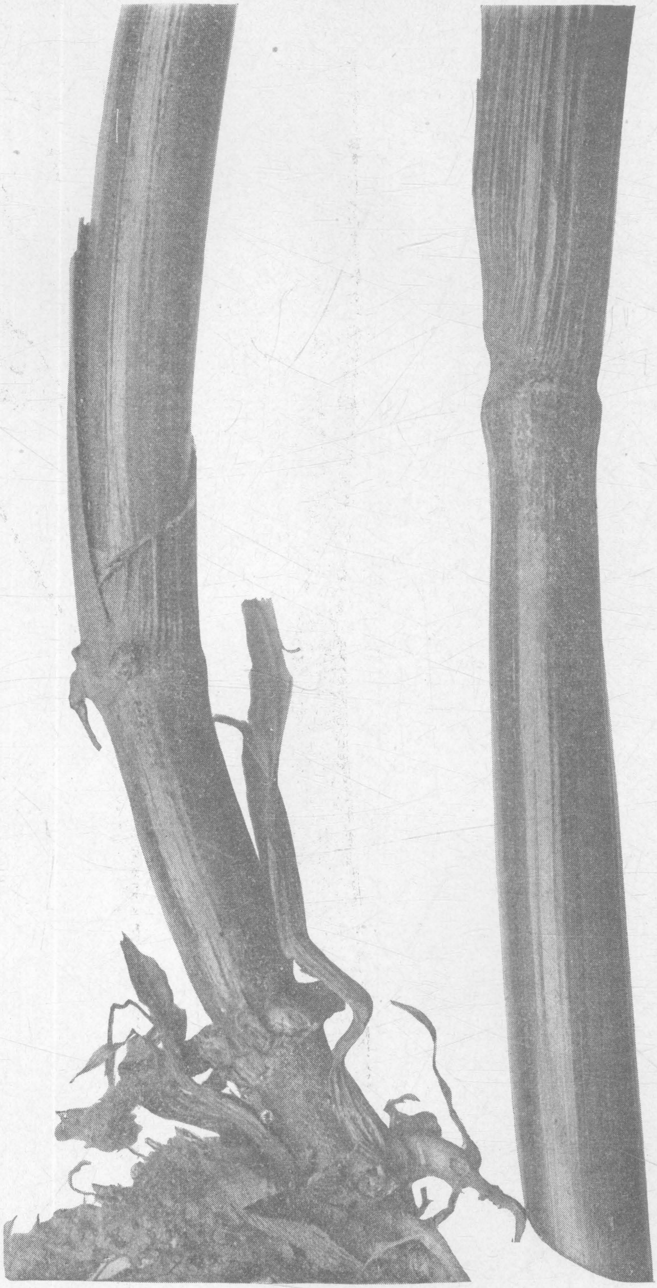

PLATE VI. Showing bases of culms of oats attacked by Anthracnose. In these specimens the roots were badly diseased. Magnified 2 1-2 times.

From a photograph by T. F. Manns.

PLATE VII. Showing same black spots (*acervuli*) of the Anthracnose fungus upon chess. At a point near the panicle many acervuli were noted on the stem. The root was also badly infected. Magnified 2 1-2 times.

From a photograph by T. F. Manns.

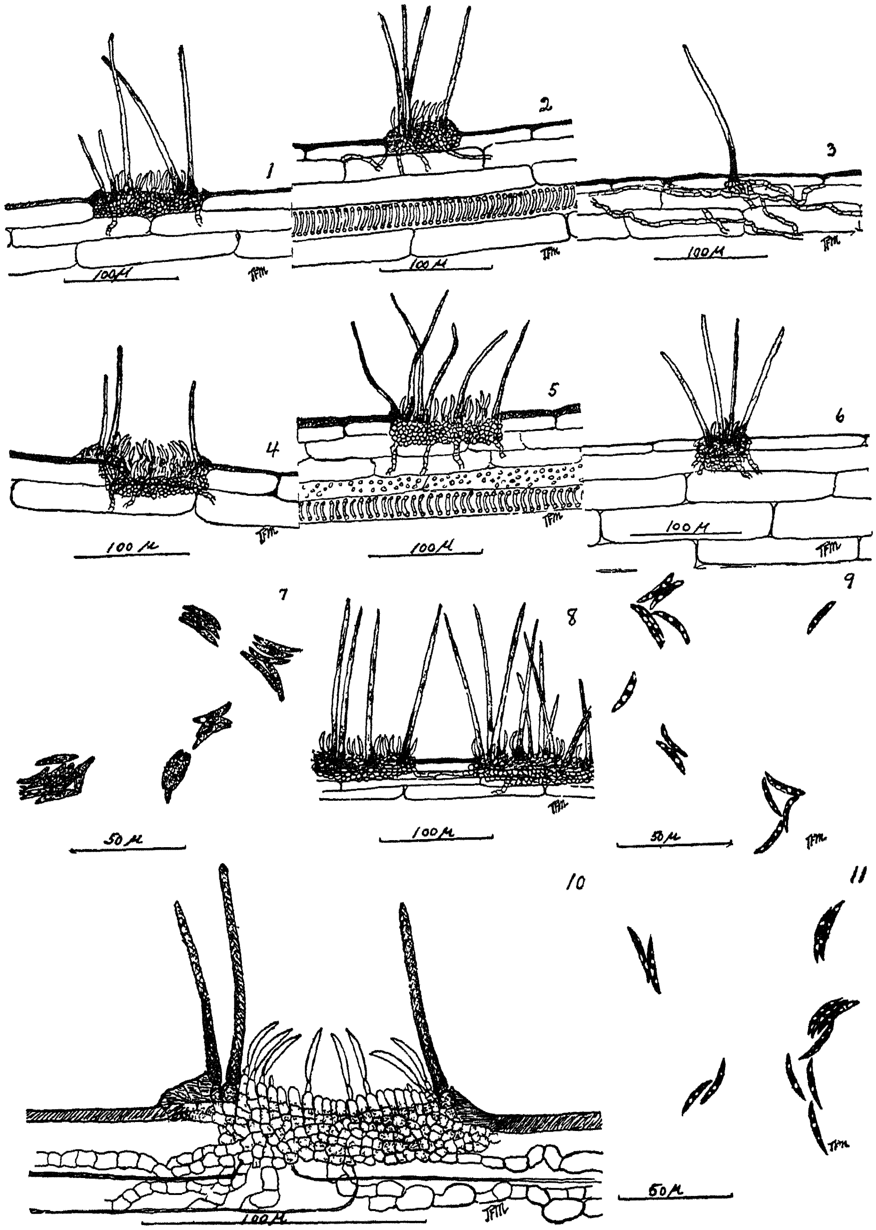

PLATE VIII. Showing details of the development of *Colletotrichum cereale* Manns, n. sp. All are from photomicrographs inked in with India ink and background later bleached out. Partly diagrammatic. Commonly X about 150. *By T. F. Manns.*

1. From wheat stem. 2. From oat stem. 3 From oat stem 4 From rye stem. 5 From timothy. 6 From orchard grass. 7 Spores of *Colletotrichum* from oat stem, artificial culture on sterile oat head X 300 8 From emmer stem. 9 Spores of *Colletotrichum* from oat stem, artificial culture on sterile rye head, carbol fuchsin stain X 300. 10. Acervulus on rye showing details of structure from micrograph X 375. 11 Spores produced on rye stem, carbol fuchsin stain X 300.

ANTHRACNOSE ON RYE NOT LIMITED TO THE RYE HEAD.

The most striking feature of the specimens from Mr. Harmon's grounds was the extended attack of the Anthracnose fungus upon the lower portion of the rye stalks, (Plate IV); beginning with the culm at the origin of the roots the Anthracnose fungus in many instances had caused blackening of the basal portion of the stems. This blackening extended upward for three or four internodes and often involved the sheaths of the leaf bases. This raised a very interesting question with respect to the possible connection between the development of the fungus at the base of the stem and that upon the rye heads. No connection has been as yet demonstrated and no proof found of the invasion of the intervening tissues.

COLLECTIONS OF ANTHRACNOSE ON WHEAT, OATS, TIMOTHY, RED-TOP, CHESS AND OTHER GRASSES.

On June 22nd, at Atwater, Portage county, an Anthracnose upon standing wheat was collected from a number of fields; the first being on the grounds of Mr. Wendell Thompson, west of Mr. Harmon's rye field. This field was somewhat badly diseased with Anthracnose and there was a peculiar whitening of the standing grain, as a whole, which made the more diseased portions conspicuous by contrast; this in the Fultz variety. On the same date a visit was made to Peninsula and to the grounds of Mr. Edgar Monegan and others in Richfield township, Summit county. In practically all of the wheat and rye fields seen in the district, specimens of Anthracnose were obtained; there seemed to be a larger amount of the disease manifest on Fultz than on Gypsy nearby, thus indicating the correctness of the theoretical assumption that the development at such time is somewhat proportional to the maturity of the wheat. According to this all earlier varieties show more conspicuous development of disease at an earlier date.

Mr. Monegan's crop of 1907 was of the Mealy variety sowed after potatoes. The promise and amount of straw for that crop were satisfactory, but the yield was only 22 bushels per acre and this badly shriveled. It was from a sample of this wheat that the centrifuge examination gave spores of Anthracnose in the laboratory. The present crop is Gypsy, sown in rich land following oats. Occasional specimens of Anthracnose were collected. Mr. Monegan's children, aged ten and twelve years, were able to gather the specimens rapidly and to detect the difference. (See Plate V). On June 22nd, at Ravenna, what appeared to be specimens of Anthracnose on timothy were collected and the next day at Wooster, specimens of what appeared to be the same Colletotrichum fungus were collected upon Gypsy wheat, upon Red-top, upon bluegrass and a few days later upon orchard grass about Wooster. On June 24th, specimens of diseased wheat were received from Mr. A. L. Walker, Cheshire, Ohio; while these indicated the presence of Anthracnose, no dark hairs (*setæ*) had yet developed, but cultures were made which a week later yielded the complete development of the fungus. Subsequently visits were made to Columbus, Gilbert and Cheshire where collections were made and observations recorded on wheat and rye. At every point the same Anthracnose fungus was collected upon wheat and rye and specimens taken. Upon wheat as compared with rye the development was limited usually to the second and third internodes of the stem and no blackening was conspicuous upon the root region and no development on the heads.

ANTHRACNOSE DISEASE UPON OATS AND EMMER.

July 5th, on a visit to the Botanist's farm in Athens county, collections were made of diseased volunteer oat stools and stools of chess. They were growing in the mulch applied about orchard trees in a wheat field. Upon both these hosts the same Anthracnose development was noted. Upon the oats the basal portions of the culms were blackened in the root region as in an extreme attack upon rye. (See Plate VI). The sheaths and stems of the second, third and even fourth internodes were likewise affected.

EFFECT OF THE ANTHRACNOSE DISEASE UPON THE GRAIN IN WHEAT AND RYE.

As earlier intimated one effect of the Anthracnose disease is to cause shriveling of the grain produced by the plants attacked; this shriveling may show a good many gradations. It is apparent from the illustrations given in the plates that such attacks must greatly weaken the affected plants. In the case of rye, where a portion of the head dies above the point attacked, the loss is practically total in so far as commercial grain from these portions is concerned. These results will appear in the details of Fig. 3 below. In the case of wheat there is no such apparent, localized attack and the effects are the general ones following the loss of vitality due to parasitic attack. With the other plants subject to the disease, similar conditions to those in wheat and oats will be found to hold. The grain from diseased plants was separated and is illustrated in the cases of wheat and rye. The amount of this shriveling will, in all cases resulting from a general attack of the disease, be proportional to the severity of the attack. Those selected for illustration were taken as representatives in weak plants attacked by Anthracnose.

The development of the disease upon chess was very similar to that on oats (See Plate VII).

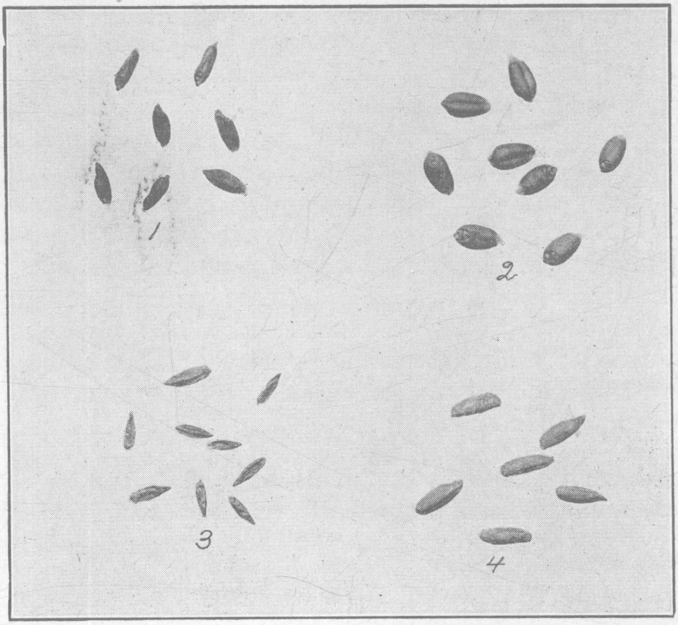

Fig. 3. Showing normal kernels of wheat and rye; also those shriveled by attacks of Anthracnose. *From a photograph by T. F. Manns.*

1. Wheat shriveled from Anthracnose attack. 2. Normal wheat kernels. 3. Shrunken rye kernels from Anthracnose attack. 4. Normal rye kernels. (All natural size). For kernels of wheat shriveled by reason of scab attack, see Fig. 4, Page 219.

The Anthracnose upon oats appeared to be less widespread in occurrence, although noted at Wooster and at a few other points.

Upon emmer at the Station, Wooster, the Anthracnose organism was collected and appeared to have inflicted marked injury, comparing in its effects somewhat closely with the effects upon wheat.

STUDIES OF THE ANTHRACNOSE ORGANISM.

Systematic study of this Anthracnose organism in the laboratory has been made by the Assistant Botanist, together with cultural and inoculation work. This work indicates that the fungus is a new one to which a description and name have been given.

In the study of an organism such as this one, systematic difficulties are met with. Systematic mycologists in the past have not covered precisely all the points that prove to be essential in generic distinctions. This has resulted in the description of certain organisms in such a way as to be referable to any one of two or more genera.* Such difficulties are met in the genera Colletotrichum (Melanconiae), Vermicularia (Sphaeropsideæ) and Chaetostroma (Hyphomyceteae). On account of these irregularities such systematists as Saccardo and Allescher note that among these genera much revision of species and greater precision as to generic characters must be given in order properly to straighten out such inconformities. The genus Vermicularia is described as having spores borne within pycnidia, the latter being surrounded with setæ; while Colletotrichum is described as having a spore layer or acervulus surrounded by setæ. This Anthracnose partakes more closely of the description of the genus Colletotrichum, hence the organism has been provisionally thrown into this genus and given the name *Colletotrichum cereale*, n. sp.

DESCRIPTION.

Colletotrichum cereale Manns, n. sp. Hyphæ shortly septate, dark brown to hyaline, 2 to 7 mmm. in diameter; acervuli originating from a compact matrix forming dark brown or black, circular to oval spots from 30 micromillimeters† in diameter with few setæ, to one millimeter or more with many setæ distributed through or surrounding the spore layer; setæ dark brown to black, at base 6 to 8 mmm. in diameter and tapering to a length of 60 to 120 mmm., with none or one to two septa. Sporophores very short, 2 to 6 x 1 to 2 mmm., conidia 18 to 26 x 3 to 4, with an average of 22 x 3.5 mmm., spindle to boat-shaped, hyaline, two to several guttulate.

Habitat: The fungus is parasitic on rye (*Secale cereale*) (roots, culms, blades and spikes), and on the roots, culms and blades of wheat (*Triticum vulgare*), oats (*Avena sativa*), barley (*Hordeum vulgare*), emmer (*Triticum spelta*), orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*), bluegrass (*Poa pratensis*), and chess, (*Bromus secalinus*); among the cereals it causes an apparent premature ripening which results in the shriveling of the kernels, seasonally causing much loss. On rye found on spikes causing much loss by *completely shriveling the head above point attacked.* The organism morphologically and on cultures appears similar from each of the hosts Cross inoculation from emmer to wheat gave positive results.

CULTURAL BEHAVIOR.

The organism was quite readily separated in pure cultures from wheat, oats, barley, rye, emmer and orchard grass. The characteristics of the organism grown from each of the above mentioned sources were noted upon nutrient agar, glucose agar, nutrient glucose agar, potato, sterile bean pod, and the sterile heads of wheat, oats, barley and emmer. In all the growths the similarity of colony, form and size of spores, color and appearance of mycelium were apparent from each of the hosts mentioned. It was hoped in placing the organism upon the several different media noted above that the perfect fruiting (perithecia) would form; however, the results were only conidial spores.

* See Die Pilze Deutschland's etc., Rab. Kryptg. Flora Abth. VI: 492.

† One micromillimeter is equal to 1-1000 of a millimeter, approximately, 1-25000 of an inch.

DESCRIPTION OF GROWTH ON STANDARD NUTRIENT GLUCOSE AGAR IN TUBE.

First day's growth: Mycelium was hyaline, 4 to 6 millimeters in extent. Second day's growth: The aerial mycelium became gray, 3 to 4 millimeters high, growth 15 to 20 millimeters in diameter; the mycelium penetrated the substratum extensively; the contact substratum became brown. Third day's growth: The aerial mycelium turned a steel gray to a light brown, the growth having extended over the entire surface of the slant; the shallow substratum had become almost black; the deeper substratum shaded off to a brown; the mycelium penetrated the full depth of medium. The growth at the end of the first week assumed the full characteristics. The aerial growth was 7 millimeters high, compact, downy, steel gray to dark gray; at the side of the tube it adhered and crept upward, the shallow substratum was black, the deeper substratum brown; the mycelium penetrated the substratum thoroughly. The conidia are boat-shaped and are borne almost sessile on the hyphae, being scattered throughout the growth though not plentiful; the setæ are very few. The conidia on artificial media are more plump, and show fewer guttulæ than on the host in nature.

ON STERILIZED OAT KERNELS.

On sterilized oat kernels the conidial growth is more plentiful. Groups of conidia one to one and one-half millimeters across, of a light pinkish color, were distributed over the kernels, and had few setæ.

GROWTH ON NUTRIENT GLUCOSE AGAR IN PASTEUR DISH.

Colonies of fungi make different characteristic growth according to the area alotted them. The following description is taken from the type of colony resulting when six colonies are placed in a three and three-fourths inch (10 cm.) dish (7 cc. of medium) which gives a colony having a diameter of about one and one-half inches (about 4 cm.) (See Plate X, Page 210).

Growth, which at first is hyaline, takes place from surface sterile pieces of stems in two to three days. In four to six days the growth reaches outward to adjacent colonies; the mycelium becomes brown. Little or no aerial growth takes place near the point of origin. Later (7 to 10 days) definite concentric waves (3 to 4 in number) of brown, aerial mycelium are apparent. In from 15 days to one month the inner, concentric, darkened area becomes studded with acervuli bearing a limited number of spores, and few setæ.

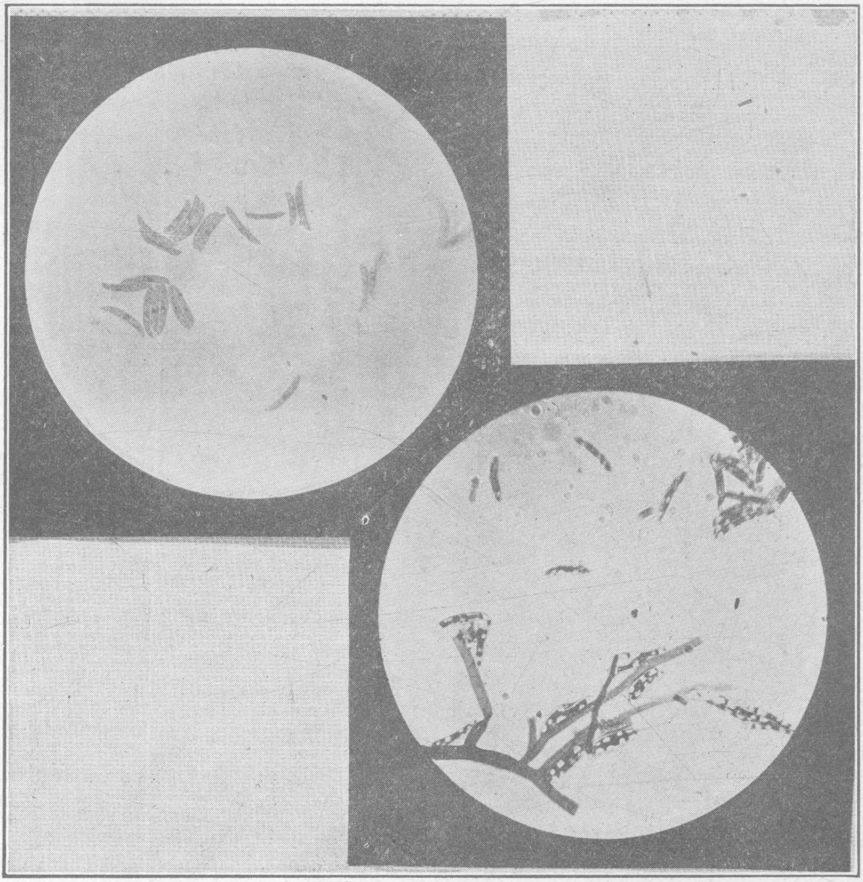

PLATE IX. Showing at top photomicrograph of Anthracnose spores grown on sterile oat kernels in tube. Magnified about 300, stained with carbol fuchsin. The figure below at right shows spores of Anthracnose from rye X 300, stained with carbol fuchsin. Observe guttulate markings. *Both by T. F. Manns.*

INOCULATION WORK.

Washings of wheat and emmer studied by means of the centrifuge showed certain samples to contain an abundance of the spores of this disease and also of the Fusarium causing scab. In carrying out a line of cross infection work with scabs of different grains, two samples of grain, viz., wheat and emmer were selected which also contained many spores of this Anthracnose disease. These spores, together with the scab disease were sprayed three times successively upon wheat. The first spraying was made upon the wheat just coming into head. The second spraying upon the same wheat when it was well in flower, and the third spraying at the time when the wheat had practically finished flowering. The results were that those plots treated with the washings containing the Anthracnose disease were infected with this disease to such an extent as to weaken and darken the straw very conspicuously (See Fig. 6). The yield was reduced one-third, this reduction, of course, being the combined effect of scab and Anthracnose. Evident shriveling was seen upon heads not infected with the scab, the result of the Anthracnose disease.

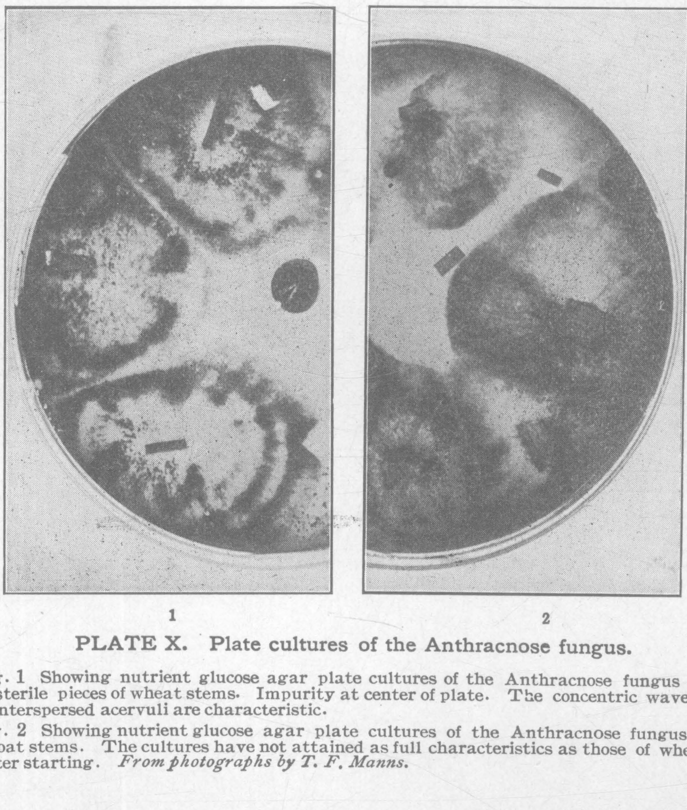

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PLATE X. Plate cultures of the Anthracnose fungus.

Fig. 1 Showing nutrient glucose agar plate cultures of the Anthracnose fungus grown from surface sterile pieces of wheat stems. Impurity at center of plate. The concentric waves of growth and the interspersed acervuli are characteristic.

Fig. 2 Showing nutrient glucose agar plate cultures of the Anthracnose fungus grown from pieces of oat stems. The cultures have not attained as full characteristics as those of wheat opposite, due to later starting. *From photographs by T. F. Manns.*

EFFECTS OF SEED TREATMENT.

During the season formaldehyde, hot water and corrosive sublimate treatments which were being tested out on smut were noted as to their action in holding this Anthracnose disease in check. Though little or no damage resulted in these treatment plots or in the checks, from the Anthracnose disease, yet the disease was noticed at the time of maturity, showing that it is widespread. Either the disease is carried over in ordinary rotations or else the disease is capable of quick dissemination during the season. The conidial spores which are so abundant in certain samples of grain are destroyed very quickly by the ordinary formaldehyde seed treatment, and such treatment is recommended to prevent distribution by seed grain.

Seed treatment is recommended with greater confidence of its application at this time, because of the equally widespread occurrence of the spores of stinking smut in the seed wheat sown in 1908. The same treatment is effective against this smut trouble as against the Anthracnose disease.

FUTURE WORK--COOPERATION INVITED.

It is not expected that the work of a single season can yield all the knowledge that may be obtainable concerning a new disease of such general prevalence as this newly described Anthracnose of our cereal grains and grasses. It will accordingly be the purpose of the Department to continue the investigation of this disease until such time as the results may fail to justify it.

Grain growers and meadow owners are most cordially invited to collect specimens of similar diseases and make notes of similar conditions observed by them and send to the Station to aid in this work. Receipt of specimens will be acknowledged and in due time proper reports or acknowledgements be made.

II THE FUNGUS OF WHEAT SCAB AS A SEED AND SEEDLING PARASITE. ALSO GENERAL ON SMALL GRAINS.

The pink covering of the diseased portions of wheat heads suffering from scab, is the fungus which causes the disease. This pink covering, upon microscopic examination, is found to consist of a mass of the threads or hyphæ of the fungus together with many characteristic curved, hyaline spores or conidia which identify it with the genus Fusarium.

Upon these diseased wheat spikes, long after harvest and more particularly upon the pink masses, there often appear dark, more or less spherical bodies, which are really spore-cases or perithecia of the perfect form or stage of the scab fungus, *Gibberella*. Within each of these Gibberella perithecia are found many spore-sacs (*asci*) of this fungus, each sac containing eight spores; each germinable spore may develop into a growth of the pink Fusarium under favorable external or laboratory cultural conditions. It is presumed that the Gibberella or perithecial form of the fungus serves the purpose of carrying the fungus over winter to enable it to attack anew the grain spikes in the form of the pink fungus, causing again the scabby heads with the pink Fusarium upon them. Yet the early disappearance of asci might well throw doubt on this form of survival. The early studies of the Botanist upon this fungus briefly stated in Bulletin 97, pp. 40-2, with illustrations of the details of the fungus, were but partially successful. The cultures of the Gibberella spores upon agar gave a uniform growth of Fusarium but he was unable to secure the development of the perithecia in the cultures.

At that time lt was possible to obtain cultures of the Fusarium from the badly diseased and shriveled kernels obtained from scabby heads. Such kernels collected in April, 1895, were found incrusted with the pink fungus and furnished the conidia of Fusarium capable of germination. Some other relations of these affected kernels were not then discovered.

In addition to the perennial interest attaching to the scab fungus upon the maturing wheat spikes and the losses in quantity and qualtity of grain caused by it, recent discoveries at this Station tend greatly to emphasize the conditions under which the scab fungus actually is carried over from year to year as a seedling parasite. These studies also show that the same fungus attacks rye, oats, barley and the spelts.

THE SCAB FUNGUS AS A SEEDLING PARASITE.

It is known to all observers that the scab disease of wheat results in premature dying of that part of the wheat spike killed by it. That the infected kernels may carry the fungus over winter in condition to reproduce itself in the spring was shown in the investigations published in Bulletin 97. The problem of whether these scab infected kernels were capable of germination in any case, appears not to have been earlier solved. Much of interest and value may come from the results of the investigations to be recorded in the following pages, with their illustrations.

In the later months of 1907 the Assistant Botanist, in addition to the centrifuge examinations of washings from shriveled grain (see page 192) made a large number of culture and germination experiments of different sorts. Among the earlier of these was the germination of sterilized wheat kernels in Petri culture dishes upon sterile nutrient glucose agar.

The kernels to be studied were first treated to sterilize them. The method used is that of an alcoholic solution of mercuric chlorid (corrosive sublimate) 2 to 1000 in 50 percent alcohol. After soaking in water the kernels were immersed in the solution, then passed through 93 percent alcohol to remove the adhering corrosive sublimate, when they were ready for plating in the culture dishes. The details of this method follow:

The treatment found most practical in learning whether kernels contain internal infection, and likewise a very efficient method for obtaining sterile plantlets of wheat and other grains, is carried out as follows: The grain is soaked in water 8 to 10 hours (preferably over night) to soften or germinate the spores most resistant to fungicides. The seed is then immersed for one to two minutes in alcohol (50 percent) containing two grams of corrosive sublimate in each 1000 cc. This solution is poured off and the seed covered with commercial alcohol, 93 percent (absolute alcohol is less liable to contain germinable spores) to remove traces of the fungicide; this latter operation is repeated. This treatment can best be carried out in flasks or tubes properly plugged. The surface sterile kernels can then be picked out with sterile forceps and placed on agar in Petri dishes; the latter should be placed in a moist chamber to aid the germination of the grain. Kernels which are found sterile upon germination may be removed by sterile forceps and placed in sterile soil or in sterile tubes for further study. As far as showing internal infection, the above method is reliable only for those organisms which manifest their presence by growth on agar or through injury to the plantlet.

GERMINATION OF WHEAT KERNELS ON AGAR.

These kernels of wheat so sterilized when placed upon sterile agar gave germination of the plant embryo, when surviving, and in addition *gave cultures or growths of all fungi surviving internally in the seed grain.* The results show an amazing amount of disease transmission in seed wheat as well as the proof of scab infection by both germinating and dead wheat kernels. The figures, Plate X, will show these results very clearly.

Out of 10 kernels sterilized exteriorly and placed in the upper dish, five proved to be germinable and free from internal infection by fungi; four germinable and in addition internally parasitized, two by the scab fungus and two with growth of another fungus, while one was dead and infected by the scab fungus. The lower figure shows three kernels dead from internal fungi, *Fusarium*, while the others are all germinating and sterile.

METHOD OF OBTAINING PERFECTLY STERILE PLANTLETS.

The middle dish in the plate shows a method* of obtaining perfectly sterile plantlets for transfer to sterile soil or other culture enclosures. In this case as in the others the seed kernels are selected and treated by the alcohol-bichlorid method before described and then transferred to the sterile, nutrient agar in the dishes.

It may be added that, by this method of external treatment to destroy adhering spores and subsequent transfer to the sterile medium, the investigator may not only obtain cultures of the internal fungi when present in seed grain of any sort, or grow perfectly healthy plantlets for other work, but he may also determine with certainty *just what fungi are internally infecting any given sample of grain.* The method is therefore adapted to secure from the interior of the seed grain the complete evidence of what it may carry in the way of disease infection. In this we have a counterpart of the centrifuge method described on pages 189 and 190, which gives the evidence as to what spores are adhering externally to the seed grain. Having determined both of these types of infection we are not yet prepared to judge how fatal these apparent parasites may prove upon the young plants; for that, studies must be made upon the young plants when subjected to the same possible infections as were before determined to be present and accordingly possible.

*The method of disinfecting seeds and germinating the same in Petri dish upon nutrient agar to obtain sterile plantlets was found practical by the writer (T. F. M.) in 1901, while working out a thesis, "Fungi of Flax Sick Soil and Flax Seed," described on pp. 26, 29. Harrison and Barlow found difficulty in obtaining sterile plants of legumes when the seeds were treated with ordinary disinfectants. (See Centr. f. Bak., II, Bd. XIX, pp. 429, 430.

PLATE X. Germinations of sterile wheat kernels upon sterile, nutrient agar in dishes. All two-thirds natural size.

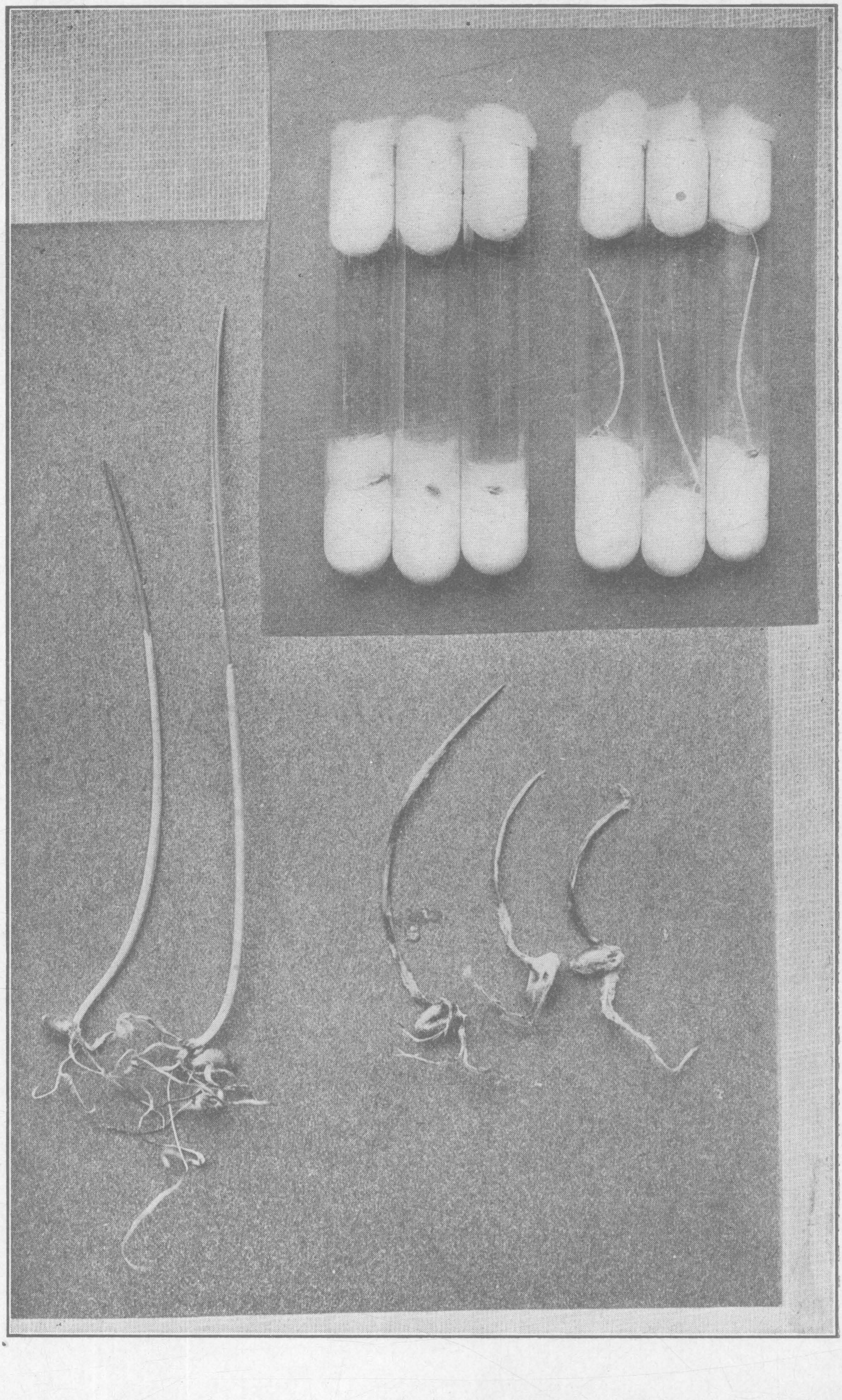
1. The upper dish or figure shows the results from placing ten wheat kernels in the dish. At the end of ten days, five of the kernels had produced healthy plantlets although some of the roots show the natural roothairs; four of the kernels produced young plantlets but were also parasitized with fungi; two with the scab fungus, Fusarium, which shows in the extended growth (white in figure) radiating from them; two with growth of another fungus; one kernel in the center was dead and gave only the growth of the fungus, Fusarium,

2. The middle dish shows the method of obtaining perfectly sterile plantlets for other work. One kernel shows growth from internal fungus and one a bacterial mass upon it.

3. The lower dish shows seven healthy plantlets, one ungerminated sterile kernel and three kernels dead without growth, due to the scab fungus, Fusarium. *Photographs by T. F. Manns.*

PLATE XI. This shows method of germinating wheat kernels in sterilized tubes containing moistened cotton.

The upper figure shows tubes having the lower inch filled with cotton and moist with tap water; then sterilized. These tubes were an efficient means to learn whether kernels were internally carrying fungi of parasitic diseases or not. The kernels were thoroughly disinfected on the surface by use of an alcohol-bichlorid method (see page 213). The three tubes on the left show kernels which carried the scab fungus internally, hence the plantlets became infected and succumbed shortly after germination. The three tubes at right contain sterile healthy plantlets (tubes reduced one-half). The lower illustration shows at the left healthy plantlets from kernels not internally infected. At the right the plantlets have made a vigorous start, but later died from scab reaching them from adjacent sick plants. (Natural size). *From photographs by T. F. Manns.*



SEEDLING WHEAT PLANTS GROWING IN TUBES.

Cultures were made of wheat plants in tubes, of which the lower portion, one inch in length, was filled with absorbent cotton and moistened with tap water. After being sterilized these served as an efficient means both of learning whether the kernels were infested with internal parasitic fungi and of the effect of these parasites in the seed upon the young plant. The kernels were thoroughly sterilized upon the surface by the alcohol-bichlorid method described on page 213, and then placed in the tubes upon the surface of the moist sterilized cotton. The illustration, Plate XI, shows the results of this method as applied to non-parasitized and parasitized wheat kernels. Those internally parasitized with the scab fungus especially were attacked by the fungus and soon perished.

It is clear from these demonstrative investigations that if these internal fungus parasites are capable of destroying the seedlings of wheat when grown under the laboratory conditions just described, similar effects may occur upon seedling wheat plants in the field. This proved to be true to a much greater extent than one can at first think possible.

THE SCAB FUNGUS KILLS SEEDLING WHEAT IN FIELDS.

The presence of the internal infection of wheat kernels by scab and the subsequent death of the seedling plants from this infection in laboratory culture directed attention to field conditions. Examinations and counts were made in several portions of the Station fields and plots.

Field conditions were found to be as indicated by the culture work, *many seedling wheat plants were found to have been killed by the scab fungus conveyed in the seed or retained by the soil.*

The casual observer may take little note of an occasional dead wheat plant in fall. To the grower this may seem of comparatively little moment, since the healthy plants may make up by stooling more than a portion of the loss in stand from such diseases. To the investigator these conditions may not be passed by. They may indeed contain the secret of the perpetuation of such diseases as wheat scab in our grain fields from year to year. To the writers the extent of injury caused to young wheat plants and the percentage of plants killed by the disease were a matter of considerable surprise.

The infection for this seedling disease is present in the seed grain as we have just shown. A portion and probably a large portion of this internal infection can be removed by the separation and rejection of all small and shriveled kernels—these may be the chief source of each year's infection. It has been shown that seed treatment can do little to kill out such internal parasites, even though pushed to the utmost limits, as in the case of treatment for the loose smut of wheat which is carried over in a similar manner.

IMPORTANCE OF SEPARATION OF LIGHT KERNELS.

The feasibility of removing the scab-infested kernels by thorough cleaning of the seed grain in the fanning mill is shown by the investigations made as to the relative weight of healthy and scab-infected kernels. It may be noted that the percent of scabby kernels found in the threshed grain does not indicate the full loss from scab, since these kernels are very much lighter than the normal and hence blow over very easily.

The following weights of normal healthy and scab-infested wheat kernels are instructive:

Twenty	large, normal wheat kernels,	.780 grams.	Average	.039	grams.
"	medium, normal wheat kernels,	.720 "	"	.036	"
"	small, normal wheat kernels,	.470 "	"	.0235	"
"	largest, scabby wheat kernels,	.470 "	"	.0235	"
"	medium, scabby wheat kernels,	.320 "	"	.016	"
"	small, scabby wheat kernels,	.220 "	"	.011	"

The relative efficiency of fanning mill cleaning in removing the scabby kernels is clearly inferred from these weights of the kernels.

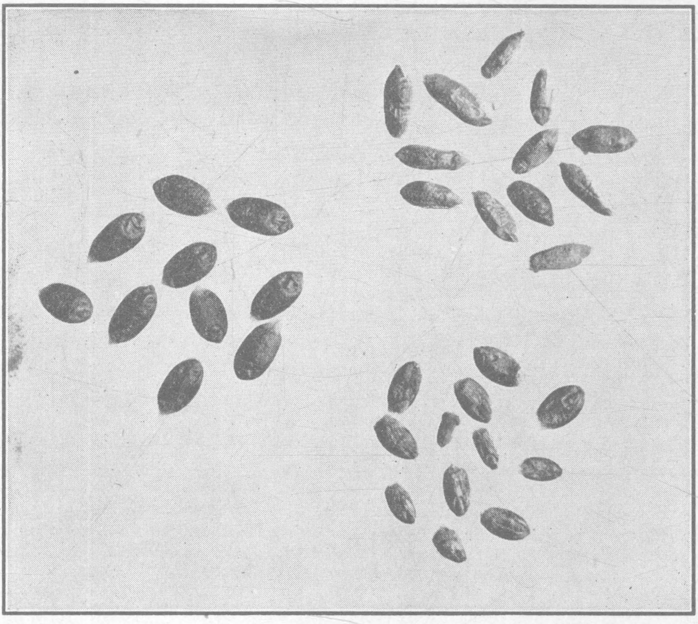


Fig. 4. Showing at the left healthy normal kernels of wheat.

In the upper right hand corner are shown scabby kernels; these will not germinate, but since they are filled with the scab fungus they are a sure means of carrying this disease. (See illustration).

In the lower right hand corner are shown kernels injured by weevil; some will make a weak germination; since they are broken and scaly they readily afford crevices for carrying fungus spores.

Scabby kernels weigh but one-fourth to two-thirds as much as healthy kernels, and the fanning mill, when properly run, will remove such. Weevil injured kernels are smaller and flatter than normal, hence will screen out. (Enlarged 1 1-2 times). *From a photograph by T. F. Manns.*

FUSARIUM ROSEUM AS A SEEDLING PARASITE.

The fertilizer plots of the Station include those in which wheat and other crops are grown in rotation, and another series in which wheat, oats and corn are grown continuously upon the same soil. The continuous wheat plots were found to be conspicuously infected with the scab.

Sections of these plots were marked off and counts were made in them during November and December, 1907. The method followed was to measure off a rod in length in a similar location in each plot and to count an equal number of drills, in all cases two drills, in each of these sections.

The following table will show the extent of the death of seedlings together with the greater number of dead plants in the plots not receiving fertilizers as well as the larger total number of plants in the fertilized plots.

Table showing number of dead and sick plants in continuous wheat plots, November-December, 1907.

Plot No.	Fertilizer	Total No Plants	Total No. Dead	Total No. Dying	Percent Dying and Dead
1	None	621	24	10	5.5
4	None	592	26	4	5.0
7	None	578	26	11	6.4
10	None	585	37	2	6.7
	*Totals and average	2,376 594	113 28	27 7	5 9
2	Acid phos. 160 lbs.; mur. potash, 100 lbs.: nit. soda, 160 lbs. per acre	678	19	8	4.0
3	Acid phos., 45 lbs. mur. potash, 30 lbs.; nit. soda, 160 lbs. per acre	673	14	4	2.7
5	Barnyard manure, 2½ tons per acre	596	20	5	4.2
6	Barnyard manure, 5 tons per acre	650	15	8	3.5
8	Acid phos., 100 lbs.; mur. potash, 100 lbs.; nit. soda, 320 lbs. per acre	610	15	7	3.6
9	Acid phos., 90 lbs., mur. potash, 60 lbs.; nit. soda, 320 lbs., per acre	633	20	8	4.4
	*Totals and average	3,340 640	103 17	40 7	3.7

*The diminished stand of plants upon the unfertilized plots as shown above, can scarcely be attributed to other differences than in disease conditions, since the rate of seeding was the same for all. By referring to Table V, page 222, it will be observed that seedling wheat plants in greenhouse were killed before reaching the surface of the soil. Under the field conditions such dead plants as were killed below the surface could scarcely be gathered by the methods followed.

In the rotation series of fertilizer plots. No. 18 gave three dead plants in a total of 200 or 1½ percent dead, and No. 19, two dead in a total of 200 or 1 percent dead. These show a much lower death rate than in the continuous plots.

The explanation of the higher percentage of diseased plants in the unfertilized plots (5.9 percent) over those with complete fertilizers (3.7 percent), probably lies in the inferior vigor of the plants in the plots where no fertilizer was added. In the continuous plots soil infection may have resulted from the seedings year after year. The dead and dying wheat plants were used as a source of cultures in the laboratory after being duly disinfected. They gave almost without exception a growth of the scab fungus, *Fusarium roseum*, although at times accompanied by other fungi. The results are commended to the attention of wheat growers. It shows the possible value of the rejection of all shriveled grain when seeding. This can be secured by screening out the smaller kernels and blowing over, possibly, some of the lighter ones.

GROWTH OF WHEAT SEEDLINGS IN GENEVA GERMINATOR.

Many germinations of suspected wheat and oat samples were made in the Geneva germinator. In this work the seeds were disinfected by the method given on page 213, so that all external fungi would be destroyed. The cloths in the germinator, which are commonly steamed in an autoclave, were disinfected in place by boiling the water in the bottom of the closed germinator. The transfer of the prepared seed was made with due precautions against external infection. The viable seeds of grain soon germinate in this apparatus and the internal infection of the diseased kernels likewise soon shows in the growth of the internal fungi. Of these, here as in the other studies in Petri dishes upon agar, the scab Fusarium was the most conspicuous internal parasite.

These seedling wheat plants in the germinator were usually soon attacked by the scab fungus wherever present and many of them were killed by it. One other conspicuous effect of the scab Fusarium was its attacks upon the germinator cloths, wherever in contact with them. First, it produced a light red color which deepened with age, showing the color characteristics described upon nutrient cultures. The discolorations of the cloths were so marked that these remained permanently darkened in the portions attacked by the scab fungus. The life of such cloths was found to be rather short with tendency to rot out along lines where the seed had lain.

GREENHOUSE EXPERIMENTS TO DETERMINE CAUSE OF DEATH OF SEEDLINGS.

While the plate and tube cultures gave indications of the nature of the parasite which caused the death of the young plants, the field conditions permitted of the possible presence of other parasites. Even the cultures obtained from the sterilized dead plant remains could scarcely show the relative aggressiveness of the different fungi found to be internally present in the seed grain.

TABLE V. Wheat seedling infection in greenhouse with cultures of *Fusarium roseum* (scab) and *Gibberella Saubinetii*, also with *Periconia pycnospora* and a second species of *Fusarium*.

No. of Row	Kind and character of infection	Total germination in 12 days	No. of plants dead at end of 12 days	14 days	22 days	34 days	Percent dead at end of 34 days
1	*Fusarium roseum* cultures from scab kernels—four tubes one month old	38	0	0	3	17	44.7
2	*Fusarium roseum* cultures, 20 seeds infected with growth from scab kernels on agar plate; *Fusarium roseum* cultures, 20 seeds infected with *Fusarium* on sterile wheat plantlets.	38	0	1	1	16	42.1
3	*Fusarium roseum* on scabby kernels	38	0	11	15	19	50.0
	Totals	114	0	12	19	52	
	Average	38	0	4	6	17	45 61
4	*Gibberella Saubinetii* cultures from Perithecia on wheat—4 gluc. agar tubes	35	0	2	5	6	17.1
5	*Gibberella Saubinetii* cultures from perithecia on wheat—1 potato tube	37	0	3	4	12	32.4
	Totals	72	0	5	9	18	
	Average	36	0	2.5	4.5	9	25.0
6	*Fusarium (roseum?)* cultures, taken from surface-sterile clover stems—3 gluc. agar tubes	38	0	2	4	11	28.9
7	*Fusarium (roseum?)* cultures, taken from surface-sterile clover stems—2 gluc. agar tubes	38	0	1	2	9	23.7
	Totals	76	0	3	6	20	
	Average	38	0	1.5	3	10	26.32
8	**Periconia pycnospora* taken internally from wheat kernels on agar plate	40	0	0	0	1	2.5
9	**Periconia pycnospora* taken internally from wheat kernels on agar plate	38	0	0	0	2	5 26
	Totals	78	0	0	0	3	
	Average	39	0	0	0	1.5	3.84
10	**Fusarium* sp., taken internally from wheat kernels on agar plate	40	0	0	2	2	5.0
11	Check—not infected	40	0	0	0	3	7.5
12	Check—not infected	40	0	0	0	0	0.
13	Check—not infected	40	0	0	0	0	0.
	Totals	120	0	0	0	3	
	Average	40	0	0	0	1	2 5

Forty kernels to the row; rows about three feet long; all seed treated with formaldehyde.

* These fungi were found in spore form somewhat plentifully in centrifuge examination, and for this reason, as well as for being found internally in kernels, they were run in this infection work. It will be noted that the infection of the seedling wheat plants by these two species is but slightly above the checks. They are accordingly regarded as saprophytic and not parasitic species of fungi.

To obtain data upon this matter of parasitism or parasitic vigor, plantings were made in the greenhouse or Pathologium of the Department. In some cases the selected plump kernels of wheat were infected with cultures of the organisms obtained from the plate cultures of the wheat kernels in the laboratory; in other cases sterilized shriveled kernels were placed in contact with the seed kernels, while in others, that is in the checks, there was no treament or infection applied. From the table it will appear that some of the internal fungi, notably the *Fusarium roseum*, whatever its source, that is, whether from cultures from wheat or clover, or whether derived directly from shriveled kernels of wheat, was very fatal. Some of the other fungi, though not destroyed by seed treatment. did not prove fatal to the seedling plants.

The results of the infection experiments with cultures of *Fusarium roseum* Lk. in the rows 1 to 3 show a very high death rate in the seedlings—the wheat plants beginning to die at the end of 14 days and succumbing rapidly within the next 20 days, reaching 45.6 percent in the end. In rows 4 and 5, wherein the infections were derived from cultures of *Gibberella Saubinetii* (Mont.) Sacc., and in which the same organism is believed to have been used, similar history of seedling infection is shown but with a reduced number of deaths. This may be due to the greatly reduced amounts of the cultures used for the infection of these rows. In rows 6 and 7, wherein the infection was derived from cultures of what appears to be *Fusarium roseum* Lk., but originally obtained from diseased clover plants, the death rate is a little higher than in rows 4 and 5.

In the check or untreated rows 10 to 13 there was a little dying attributable to internal troubles.

Contrasting sharply with rows 1 to 7 are the results obtained from infection attempted by means of *Periconia pycnospora*, a common mold upon decaying matter, rows 8 and 9, in which the death rate seems comparable with the checks as it is also in row 10 in which another species of Fusarium was used. Both the Periconia and the last named Fusarium are therefore regarded as saprophytic fungi, though occurring internally in wheat kernels.

INFECTION OF WHEAT SEEDLINGS LIMITED TO EARLY PERIOD.

Studies were made of the possible dying of the seedling wheat plants, both in field and in the above tests, subsequent to the dates of counting or note-taking mentioned in the table. There did not appear to be later dying of plants, and such plants as passed the earlier period safely were commonly able to attain maturity. After one month is passed infection ceases. This raises the questions of the limits to the attack of the Fusarium and of the resistance of the wheat plant. The basis of the later apparent immunity was not investigated. It occurs to one that the external tissues may offer the explanation of this reduced susceptibility to attack.

THE SCAB FUSARIUM ALSO A CLOVER PARASITE.

A specific point in the table is the evidence it shows that the scab fungus on wheat, *Fusarium roseum*, is likewise *an aggressive* parasite upon clover and *therefore a source of clover sickness.* In addition to the evidence offered in the wheat infection work unexpected results were obtained in cultures from clover stems.

On a visit to Athens county early in December, 1907, cultures were made from sick clover stems, seeking especially the clover anthracnose fungus. In a total of 20 tubes used in one field, 18 of them gave cultures of what subsequently proved to be *Fusarium roseum.* These cultures were used in the infection work above described.

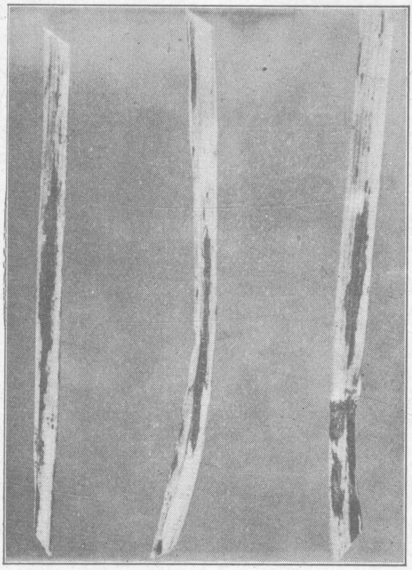


Fig. 5. Showing stems of red clover, *Trifolium pratense* L., with definite, elongated lesions caused by a parasitic fungus identical in cultural characters with *Fusarium roseum* Lk. The conidial or spore development of the fungus occurs as grayish pustules within the lesions. (Natural size).
From a photograph by T. F. Manns.

A diseased condition of clover stems in the north-east field at the Station was studied in 1907-8. The diseased stems showed definite, depressed, oblong or elliptical lesions; in the central portions of these lesions were outgrowths of a grayish color, which upon microscopic examination proved to be the sporodochia of the fungus. (See Fig. 5). When tested by laboratory studies the grayish fungus proved to be *Fusarium roseum* Lk. and was in no wise distinguishable from that obtained from other sources.

OAT SEEDLINGS KILLED BY THE SCAB FUNGUS.

Plantings of oats were made in the greenhouse following the removal of a subsequent crop of wheat plants described above. The seedings of oats were made directly over the rows of wheat showing the highest death rates. It was found that the young oat plants suffered after the same manner of wheat plants from the parasitism of *Fusarium roseum.* Some plants were killed before they reached the surface of the soil, others were subsequently killed by the attacks of the fungus. These worst diseased rows gave 46 percent and 52 percent respectively of dead plants at the end of 30 days.

THE SCAB FUNGUS A ROOT AND SEEDLING TROUBLE OF ALFALFA.

In the spring of 1908, examinations of alfalfa plants which were dying out in spots in the unlimed portion of a field at the Station showed definite dark sunken lesions upon the roots; some plants showed a light yellow streak up the stem on the side where the root lesions appeared. Artificial culture work upon such affected roots and stems brought out in practically every instance a Fusarium with cultural characteristics similar to *Fusarium roseum* Lk. Portions of such diseased stems and roots were planted with alfalfa seeds in greenhouse alongside of which was run a check row not infected. Many of the seedlings in the infected row never reached the surface, and those which did continued dying until only 7 percent remained. In the non-infected check row 97 percent of the seed germinated with healthy seedlings which continued to grow.

Further plantings of alfalfa seed upon a spot in soil in greenhouse, sick with *Fusarium roseum*, showed a continued dying of the alfalfa seedlings till all had succumbed. Cultural work upon seedlings thus affected, as with field specimens, brought out from the tissues a fungus identical in cultural characteristics with *Fusarium roseum* Lk.

These significant results upon clover and alfalfa show how necessary it is to place clover and alfalfa plants under the best possible conditions for growth. It is not improbable that, in future, this fungus must be reckoned with in seedings to be made. Certainly adequate applications of lime are in favor of the growth of these legumes, whether or not the lime has a checking effect upon the fungus directly.

THE SCAB FUNGUS ALSO GENERAL ON SMALL GRAINS.

From macro-examinations and centrifuge microscopic examinations made in 1907-8 of samples of seed wheat, oats, barley, rye, emmer and spelt, it was very apparent that each and all of these grains contained the scab disease. That is, the kernels were either scabby or covered with scabby glumes, sometimes having the perithecia of Gibberella also present, (see Plate XIV, lower illustration, opposite page 232) or by means of the microscope in examination of the precipitate from the washings of grain samples, the presence of Fusarium (scab) spores was readily revealed. (See Plates I and II showing micrographs of spores found in grains, also Tables II, III, IV, V, pages 192, 197). In wheat the amount of scabby kernels found in the threshed grain for the season of 1907 was usually from 1 percent to 3 percent; the largest amount found in any one sample was a little over 10 percent. These amounts do not signify that this is the total loss from scab. The spikes of wheat, barley, rye and emmer in many instances give full loss above the point attacked; also scabby kernels are much lighter than normal kernels (see table, page 219) hence many blow over in threshing. From the writers' observations the season of 1907 was very favorable for the production of scab on all grains; this was probably due to the abundant moisture.

In oat scab the glume (chaff) is usually the part which bears the more conspicuous growth of the disease, hence in threshed samples most of this evidence of the disease is not found. From field observation made in 1908 it appears that the kernels of most oat grains attacked become entirely shriveled, so that upon opening the hull little if any kernel is to be found. These empty hulls, distinguished by having a very light pink color, were quite plentiful among the oat samples of 1907-8. The following data shows the percent of empty hulls (not in all cases having pink coloring) found in samples of oats grown at this Station in 1907 and 1908.

EMPTY HULLS IN STATION OATS IN 1907 AND 1908.

Variety	Empty Hulls 1907	Empty Hulls 1908
Green Mountain	6.0 percent	6.6 percent
Sensation	5.0 "	8.1 "
Improved American	3.8 "	4.5 "
Lincoln	.5 "	8.0 "
Siberian	10.3 "	11.8 "
Long's White Tartar	2.0 "	12.1 "

From centrifuge micro-examinations of oats from the crop of 1907 it was evident that the seed was in most cases covered with scab spores (see Table IV, page 197). Germination tests made with a large number of samples showed that many kernels failed to grow owing to scab infection. The loss in oats from scab is considerable. It may equal that of wheat, though the fact, that oats and other spring grains usually ripen in a drier part of the season than does wheat, would apparently tend to reduce the amount of scab.

Observations upon fields of barley, rye, emmer and spelt show these grains to be also very susceptible to the attack of scab. Emmer, spelt and barley show even greater losses than rye. A field of emmer grown on the Station grounds in 1905 showed almost 50 percent (estimated) loss by shriveling due to this disease.

CROSS INFECTION WORK WITH SCAB ON WHEAT AND OATS IN THE FIELD--1908.

From macro-examinations, artificial cultures, dying of wheat and oat seedlings and microscopical studies of scab, there appeared much similarity in the organisms causing the scab of the different

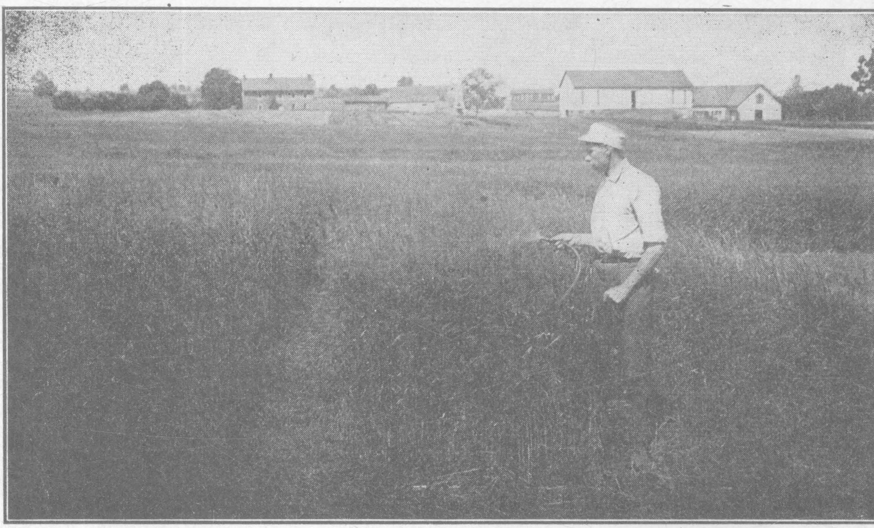


Fig. 6. Showing method of infecting field plots by means of hand spray pump with washings of grain containing spores of Anthracnose and scab.

From a photograph by T. F. Manns.

Fig. 7. Showing at left check plot: At right plot infected with washings from emmer containing many Anthracnose and scab spores. Observe the weakness of straw due to the Anthracnose. The yield was reduced one-third.

From a photograph by T. F. Manns.

grains. Heretofore the scabs of wheat[1], oats[2], barley[3] and rye[4] have each been given different specific names, which would indicate that each of the organisms found on these different grains is entirely distinct.

In hopes of throwing further light on this subject a number of plots of wheat (see Figures 6 and 7) and oats were laid off for infection work in the Station fields. The infections were made at the time these grains were flowering. The material for infection was obtained from washings of wheat, oats, barley, rye and emmer, in samples of these grains which showed upon centrifuge micro-examination an abundance of scab conidia. These washings were sprayed by means of hand spray pump upon the separate plots upon each of three successive days, using at each time three quarts of seed grain and two quarts of water. The plots were 6x8 feet. An equal number of check (unsprayed) plots, were also run.

In order to learn at what period the infection took place, individual plants were labeled in each infected bed at spraying as follows:

Thirty heads which had flowered, thirty heads in flower, and thirty heads which had not flowered. The sprayings on the wheat plots were made June 3, 4 and 5. The atmosphere was quite moist, and therefore favorable for infection. The infection which followed was very marked especially on those plots sprayed respectively with washings from emmer and oats, where those heads in flower at time of spraying showed respectively 100 and 89.5 percent infected. The average percent of infected heads in the five check plots was less than one percent. (See Tables VI and VII.)

It would appear, from this infection work on wheat, that it matters little what the source of scab conidia, whether from oats, emmer, barley, wheat or rye, if they are placed on wheat at the flowering time under favorable weather conditions, infection readily takes place. This would indicate that the cause of these scabs is a fungus identical on each of these different hosts. Gibberella perithecia (see Fig. 2 in lower illustration, Plate XII) were found on some of the scabby glumes in the plot sprayed with emmer washings, while grain was still standing in the field, which would further tend to point out that *Gibberella Saubinetii**, *Fusarium roseum* Lk. and these specifically named scabs, are one and the same organism.

[1] *Fusarium culmorum* (W. Sm.) Sacc. *Fusisporium* W. Sm., Diseases of Field and Garden Crops London 1894, p. 209.

[2] (a) As a saprophyte—*Fusarium avenaceum* (Fr.) Sacc. *Fusisporium avenaceum* Fr. Syst. Myc. III, p. 444.

(b) As a parasite on kernels and seedlings. *Fusarium avenaceum* on oat, E. Rostrup. No. 9 Rostrup Tiedsskrift for Landökonomi. Köbenhavn, 1893. (Note, Rostrup here shows that this fungus winters on and within the oat kernel and attacks the young plantlet).

[3] *Fusarium hordei* (W. Sm.) Sacc. *Fusisporium* W. Sm. Diseases p. 210, 1894.

[4] *Fusarium heterosporium* Nees. Jahrbuch. d. deutsch. landwirth. Gesell. 1892.

* *Gibberell Saubinetii* (Mont.) Sacc., Mich. I, p.513. In which note is made of it being found on the dead (dry) stems of *Zeae, Stipae, Tritici* and on dead material of many other genera. Note is also made of the similarity or identity of the mycelial and conidial growth of *Gibberella Saubiuetii* to that of *Fusarium roseum* Lk.

The following tables give the results of this infection work:

TABLE VI. Scabs from different sources when sprayed on wheat three times gave the following percents of heads infected.

Plots sprayed with washings	Flowered	Flowering	Before Flowering	Marked heads, ave. percent affected
Of scab conidia from oats	78.5	89.5	42.3	70.1
Of scab conidia from emmer	77.7	100.0	55.5	77.8
Of scab conidia from barley	88.8	63.6	22.2	58.2
Of scab conidia from wheat	53.3	80.0	66.6	66.4
Of scab conidia from spelt, not counted*	....	....	....	....
Average	74.6	83 8	46.6	68.1

* Percentages about equal to wheat.
The checks (5 plots) averaged less than one percent of the heads infected with scab.

TABLE VII. After threshing. Counted 200 seeds and took percent.

Plot No.	How treated	Percent of yield	Percent scabby	Percent shrunken	Percent sound and plump
1	Check	100.	0.0	7.5	92.5
2	Sprayed with oat scab	88.7	1.5	6.5	92 0
3	Check	100.	0.0	8.5	91.5
4	Emmer scab	66.6	0.9	9.0	82·0
5	Check	100.	0.0	5.0	95.0
6	Barley scab	86.9	2.0	3.5	94.5
7	Wheat scab	81.8	0.5	6.0	93.5
8	Check	100.	0.0	6.5	93.5
9	Spelt scab	100.	0.5	3.0	96.0

OAT INFECTION WITH DIFFERENT SCABS.

The size of plots in this work and source of the infection material were the same as those for the wheat infection work. The sprayings of the infection material on the oat plots were made June 29th. July 1st and July 3rd. The first spraying was followed within a few minutes of completion by a thunder shower which probably washed off most of the infection material. The sprayings of July 1st and 3rd, were made when the atmosphere was very dry, and were followed by very droughty weather. The infections, though definite on each of the sprayed plots, were much less marked than in the wheat plots. This may be accounted for by the excessively dry weather during the period of infection. The highest infection on oats came from the wheat washings from which somewhat over 10 percent of the panicles showed glumes more or less infected. The next highest infection was from emmer which was over two percent. Washings from oats gave somewhat over one and one-half percent. Barley and rye each gave somewhat over one percent. Two out of the five checks showed no infection, while the average of the five checks was two-fifths of one percent.

These results, though not marked, would again seem to indicate the indentity of the organisms causing these scabs.

FUSARIUM INFECTION NOT THROUGH THE STEM.

Further conclusions drawn from these field infections with scab on wheat and oats indicate that the flowering period is the time when the greatest infection takes place, though heads which had not already flowered and those which had passed the flowering stage at time of spraying readily became infected.

A line of infection work carried out in the greenhouse would indicate that scab infection does not take place by reaching the head through permeation of the stem. Sterile wheat plantlets obtained by surface disinfection (see method page 213) and plate method, were placed in sterile soil in seven-inch pots, five plants being placed in each. The plantlets were infected at the roots with the scab fungus from scabby kernels, and also from cultures of *Fusarium roseum* from sick clover and wheat plantlets; twelve pots were run including four checks. In the infected pots several of the seedlings succumbed to the disease during the first three weeks. The remainder reached maturity. No scab was found upon any of the plants.

It may be further noted that in studying this disease as a seedling trouble of wheat a plentiful production of conidia was observed upon the dying roots. This would be a source from which conidia would reach the heads at flowering time, carried by winds, insects, or spattered on by heavy rains; these means are undoubtedly the natural ways of infection.

THE RELATION OF GIBBERELLA SAUBINETII (MONT,) SACC. TO FUSARIUM ROSEUM LK., AND THESE SCABS.

Extentsive artificial culture work was carried on in 1907 and 1908 upon *Gibberella Saubinetii*, *Fusarium*, *roseum*, and the different scabs of wheat, oats, barley, rye, emmer and spelt. The Gibberella cultures were taken directly from perithecia on scabby glumes, or from perithecia upon the stems of wheat, oats, barley. rye, emmer and spelt. (See Plate XIV). *Fusarium roseum* cultures were obtained from dead plants, dying wheat plantlets, and from sick clover. The scab cultures were taken directly from scabby kernels. These different organisms (Gibberella, Fusarium and scabs) were run on the following artificial media, viz., nutrient agar, glucose agar, nutrient glucose agar, all .5 percent acid to phenolphthalein. Further, the nutrient glucose agar was varied in acidity from .5 percent to 1.5 and 2.5 percent to phenolphthalein. In alkalinity the medium was made .5 percent and 1.5 percent to phenolphthalein. Potato plugs and green bean pods were also used. The following were also used; sterile heads of wheat, oats, barley, rye and emmer in tubes containing at bottom about one inch of absorbent cotton to retain moisture. In another series the heads were placed in tubes containing an inch of moist soil. In still another series straw and moist soil were used. In still another series seeds having their glumes on, were placed in tubes containing moist soil. In all cases these media were thoroughly sterilized in the autoclave, previous to inoculation.

In all the above culture work failure to get perithecia resulted, though in several cases bluish heaps of perithecial-like structures devoid of asci or spores were observed. The cultures in all their characteristics were identical from the Gibberella, the Fusarium and the scabs, above mentioned (see illustration of scab cultures, Plate XIII).

As a seedling trouble in infection work on wheat the results were practically the same with cultures of Gibberella, *Fusarium roseum* and the scabs. (See Table, page 222).

Gibberella perithecia produced upon the scabby glumes of emmer, wheat, barley and oats (see lower illustration, Plate XIV) are similar in measurements and other characteristics.

Wheat sprayed in the field with scab conidia from emmer produced scabby glumes bearing perithecia of Gibberella.

Evidence of the identity of these different organisms seems to be indicated from this work.

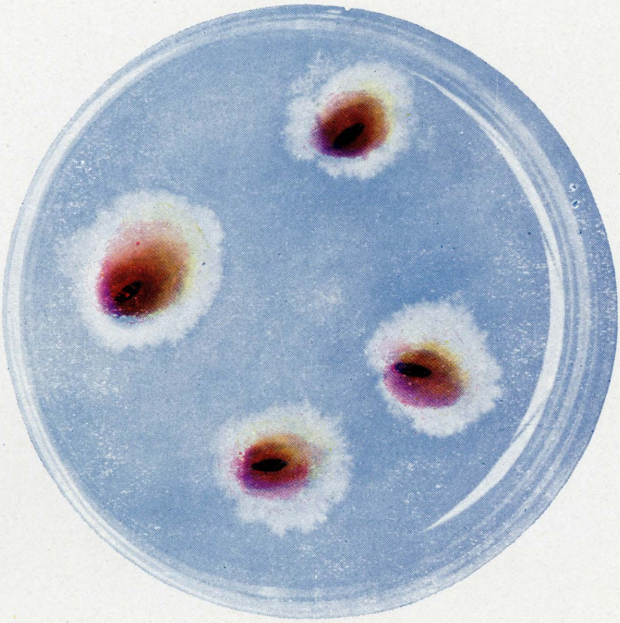
REMEDIES FOR THE SCAB DISEASE IN GRAINS.

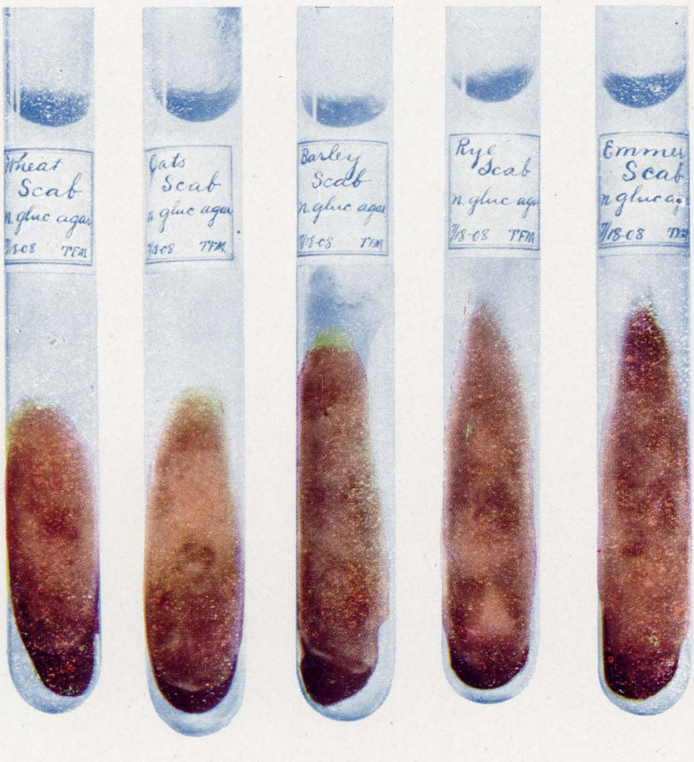
From the detailed studies given on the preceding pages, it is apparent that complete prevention of the scab trouble will require the use of every available means at our command. The presence of stinking smut in 68.4 percent of samples examined; of scab in 98.9 percent, and of Anthracnose in 92.6 percent of the samples of wheat in 1907, with nearly equal percentages in seed oats having spores of scab, anthracnose and smuts, shows seed treatment to be necessary. Leaving out the Anthracnose and scab diseases described in this bulletin, the stinking smut of wheat and the loose smut of

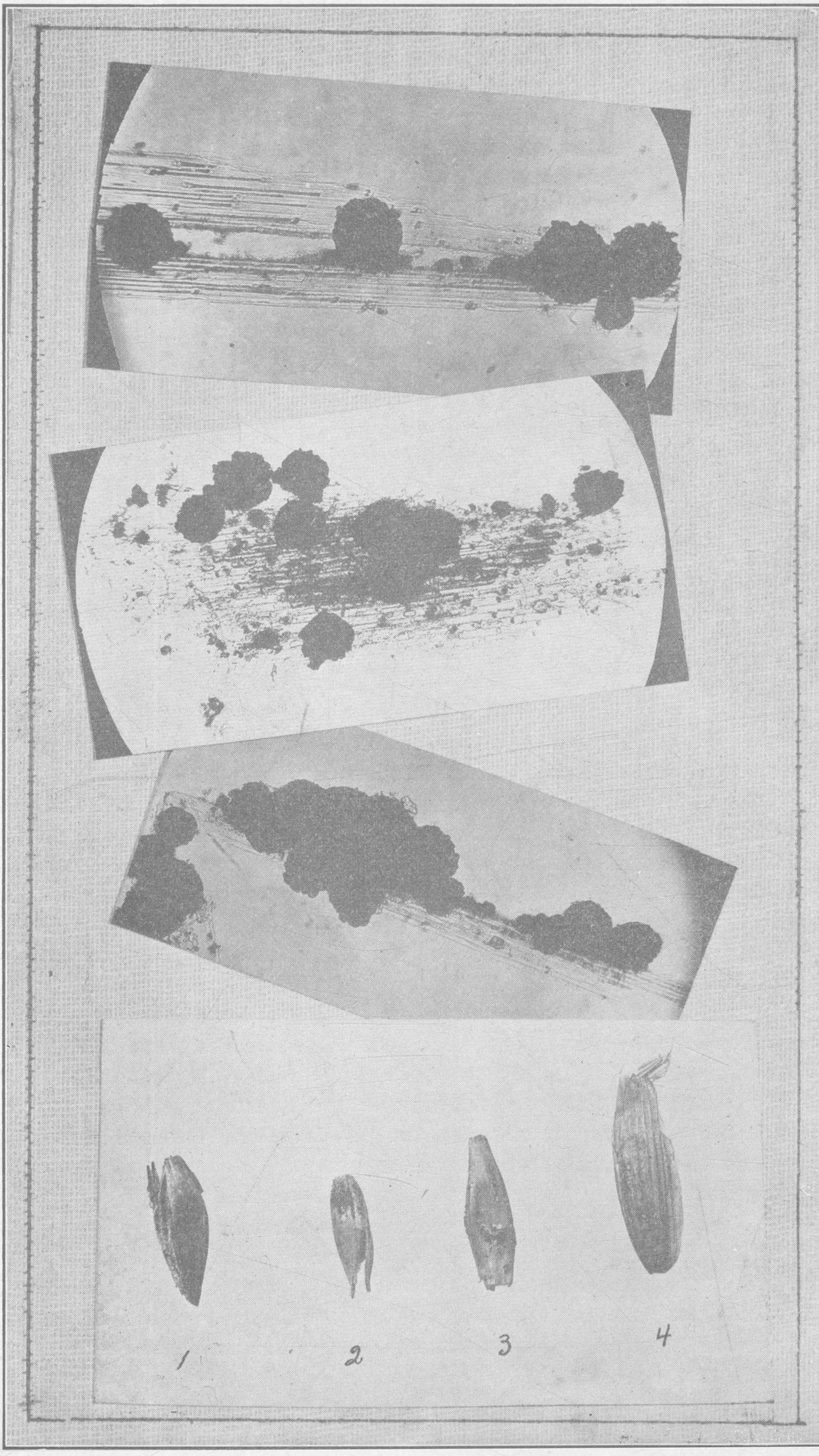
PLATE XII. Showing nutrient-glucose-agar, tube cultures of the scabs of wheat, oats, barley, rye and emmer, originally from scabby kernels of these different grains. These scab cultures on this medium acquire on the third day a light, rose-pink color, which deepens with age until the pink is shaded off to a yellowish brown. Observe the similarity of growth and color (See pages 230 and 231). Cultures four weeks old. On glucose-agar the color is a dark, rose red.
From a photograph with water coloring by T. F. Manns.

PLATE XIII. Showing nutrient-glucose-agar, plate cultures of the scab fungus from surface-sterilized, scabby, wheat kernels. Observe the increased reddening near the grain due apparently to the carbohydrate (starch) within the kernels. These kernels harbor the scab fungus and are a means of field infection. *From a photograph with water coloring by T. F. Manns.*

PLATE XIV. Upper figure shows perithecia of scab on rye X 45. Second figure from top shows perithecia of scab on wheat X 45. Third figure from top shows perithecia of scab on oats X 45. Lower figure shows: 1. Emmer with perithecia of scab on glume. 2. Wheat with perithecia of scab on glume covering scabby kernel, inoculated from emmer as noted elsewhere. 3. Barley with perithecia of scab on glume. 4. Oat with perithecia of scab on glume. The kernels covered by these glumes bearing perithecia were scabby. All these types of *Gibberella* are identical in size and appearance of perithecia, asci and ascospores. *From photographs by T. F. Manns.*




Wheat Scab n. gluc agar 7/18-08 TFM
Oats Scab n. gluc agar 7/18-08 TFM
Barley Scab n. gluc agar 7/18-08 TFM
Rye Scab n. gluc agar 7/18-08 TFM
Emmer Scab n. gluc agar 7/18-08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oats call for seed treatment; in addition to the destruction of these smut spores this treatment will kill adhering spores of scab, anthracnose and some other fungi. Seed treatment by the formalin method is urged for these reasons. It will help to keep down all these parasitic troubles.

For complete scab control the light weight of scab-infested kernels of all sorts of grain attacked by this disease and especially in wheat as shown by the average weight of these kernels (page 219) points the way to great relief by thorough screening and fanning mill cleaning of grain intended to be used for seed. By sacrifice of the small kernels of healthy character through screens and by blowing out the lighter, scab-infected kernels a very large proportion of the diseased kernels will be removed. Too much insistance can not well be made upon the importance of this recleaning of seed grains with the definite purpose of removing a moderate percentage of the small and light grain. These screenings, etc., will have a certain feeding value when separated but when *sowed they have no seeding value* and are besides a *positive source of disease in the grain crop.*

SUMMARY.

FIRST PART.

1. From the work described in the preceding pages, it seems clearly proved that there is prevalent in Ohio, and doubtless in neighboring states as well, an Anthracnose disease attacking rye, wheat, oats, emmer, and various grasses, causing much injury to the cereals through the resultant shriveling of grain.

2. After study upon the affected host plants, and in standard culture media in the laboratory, it is concluded that the organism causing this disease upon the different hosts is essentially the same and to it the name *Colletotrichum cereale* n. sp. with specific description, has been given.

3. This fungus causes especially noteworthy losses in the yields of rye fields in which it prevails. The attacks of this Anthracnose are shown by the premature dying of those portions of the spikes above the point of its specific attack, resulting in almost total loss of the grain in these dead portions. The fungus also attacks the roots and basal portions of the rye stems, thus producing a blackened appearance of the attacked parts and causes impaired vigor in the plant as a whole. This cannot but result in impaired filling of the grain.

4. Upon wheat the same disease has prevailed as upon rye, but with this difference: no special attack of the wheat head and less root attack have been observed, while the basal portions of the stems, and the basal leaf-sheaths are conspicuously attacked, accompanied by premature whitening and ripening of the plant and much shriveling of the grain.

5. Similar diseased conditions have been studied upon oats, emmer, blue-grass, red-top, orchard grass and timothy. These have been ascribed to the same Anthracnose fungus and result in similar impairment of the vigor of the host plant when attacked.

6. The spores of this new disease as well as those of the scab and the well-known smuts are readily disseminated through seed grain, as is shown by the results of centrifuge examinations made of the washings from suspected grain (see page 191). Seed treatment by the use of the formaldehyde drench or other effective method will readily destroy the Anthracnose spores carried by the grain, and is recommended.

7. While the seed treatment described above will be effective in destroying the infection carried by the seed grain, the occurrence of the fungus upon the straw from diseased grain fields and upon the culms of grasses, which may be grown in the rotations practiced, would indicate other more general sources of infection from the Anthracnose fungus.

8. The possibilities of more complete control of this newly described disease can be determined only by fuller study carried through several seasons. The continued cooperation of the grain growers of Ohio in this future study is solicited.

SECOND PART.

9. Previous studies by the Botanical Department upon the fungus of wheat scab, *Fusarium roseum* Lk. and of the results of the growth of the spores of its probable perithecial form, *Gibberella Saubinetii* (Mont.) Sacc., upon culture media have been continued and verified.

10. These further studies show that the scab fungus certainly survives as an internal infection in scab-infested kernels of wheat. Pure cultures have been obtained of this *Fusarium roseum* Lk. by placing externally sterile infected kernels upon agar in Petri dishes; cultures of other fungi which survive by internal infection of the seed grain, have also been obtained. Likewise a method is given for securing perfectly sterile plantlets to be used for other purposes.

11. The work done demonstrates that the scab fungus not only survives in dead wheat kernels but also in those capable of germination.

Germinations of externally sterile kernels of wheat have been made in the Geneva germinator, in sterile tubes, and soil in the greenhouse.

12. All these tests prove that the scab fungus, *Fusarium roseum* Lk. under such circumstances, *is an aggressive seedling parasite attacking and killing the young wheat plants* under a month in age.

13. Examinations and counts in the continuous wheat plots of the Station at Wooster, show that in 1907 there was a large loss of the seedling wheat plants, killed by this scab fungus. In the unfertilized plots there was an average of 5.9 percent of the plants destroyed while the fertilized plots showed 3.7 percent. In rotation fields this loss was from 1 to 1½ percent only.

14. Infection experiments in the greenhouse (Pathologium) by use of cultures of *Fusarium roseum* Lk. from wheat, of *Gibberella Saubinetii* (Mont.) Sacc. and of *Fusarium roseum* from clover, as well as sterilized dead scab kernels, showed a high death rate in the seedlings as a result of the infection. Infections by use of a mold fungus, *Periconia pycnospora* gave about the same result as in the check portions.

15. This infection work together with field work and cultures from dead clover stems indicate that *Fusarium roseum* Lk. is an active parasite upon red clover (*Trifolium pratense* L.) and is a cause of clover sickness in clover fields seeded after wheat. Evidence is also found of its parasitism upon alfalfa resulting in possible sickness.

16. Centrifuge examinations of oats, barley, rye, emmer and spelt made in 1907 showed the presence of what appeared to be spores of *Fusarium roseum* in all these grains. These results were verified by examination of the grains themselves and by field studies in 1908.

17. Culture work carried out in 1907-8 upon *Gibberella Saubinetii*, *Fusarium roseum*, and the scabs of wheat, oats, barley, rye and emmer shows characteristics with each and all of these organisms that are similar, thus indicating their identity.

18. Microscopic study of Gibberella perithecia from glumes of emmer, wheat, barley and oats, also from stems of these grains, together with rye and spelt show the fungus on all to be apparently identical.